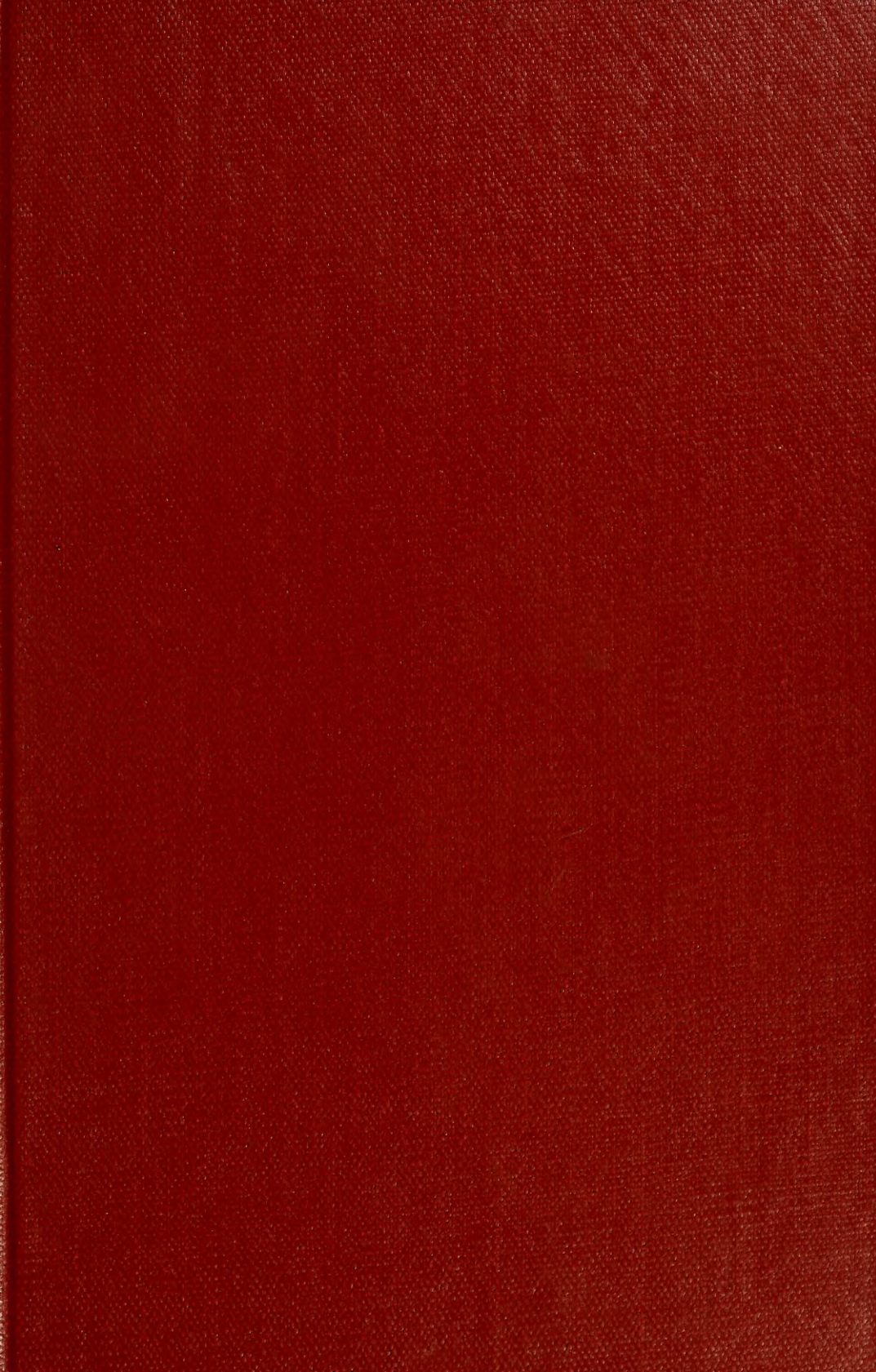






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No. 275

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A REEXAMINATION OF CHITINOZOA FROM THE
CEDAR VALLEY FORMATION OF IOWA WITH
OBSERVATIONS ON THEIR MORPHOLOGY
AND DISTRIBUTION

By

JAMES B. URBAN

1972

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JAMES B. URBAN

December 6, 1972

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A REEXAMINATION OF CHITINOZOA FROM THE CEDAR VALLEY FORMATION OF IOWA WITH OBSERVATIONS ON THEIR MORPHOLOGY AND DISTRIBUTION*

JAMES B. URBAN

Geosciences Division, University of Texas at Dallas,

ABSTRACT

Chitinozoa have been recovered in seven of fourteen sections from the Cedar Valley Formation of Iowa. The assemblage consists of 13 species and includes species of *Hocgisphaera* and *Desmochitina* which had not been previously reported from the formation. The Chitinozoa show a distinct stratigraphic and geographic distribution that is believed to be due to a biofacies restriction. Three new species are described.

INTRODUCTION

The Cedar Valley Formation is predominantly limestone and is the most extensive Devonian formation in Iowa. Rocks of the Cedar Valley Formation crop out in a belt extending from southern Minnesota across the eastern part of the state and south into Illinois and Missouri. Maximum thickness of the formation is approximately 500 feet in the subsurface of southwestern Iowa. Thickness along the outcrop area seldom exceeds 100 feet. Three members (Solon, Rapid, and Coralville) are commonly recognized in the formation (Table 1).

Collinson and Scott (1958) first reported Chitinozoa from the Cedar Valley Formation. They described an assemblage from a locality in northwestern Illinois believed to be the Solon Member of the Cedar Valley Formation. Dunn (1959) described a chitinozoan assemblage from the Cedar Valley Formation in Iowa by using a composite section from two localities to represent the entire formation. One locality was an outcrop section in the River Products Company Quarry, north of Iowa City, Iowa. The section consisted of most of the Rapid Member and the entire Coralville Member. The Solon Member plus the lower few feet of the Rapid Member were represented by samples from a core taken near Ottumwa, Iowa.

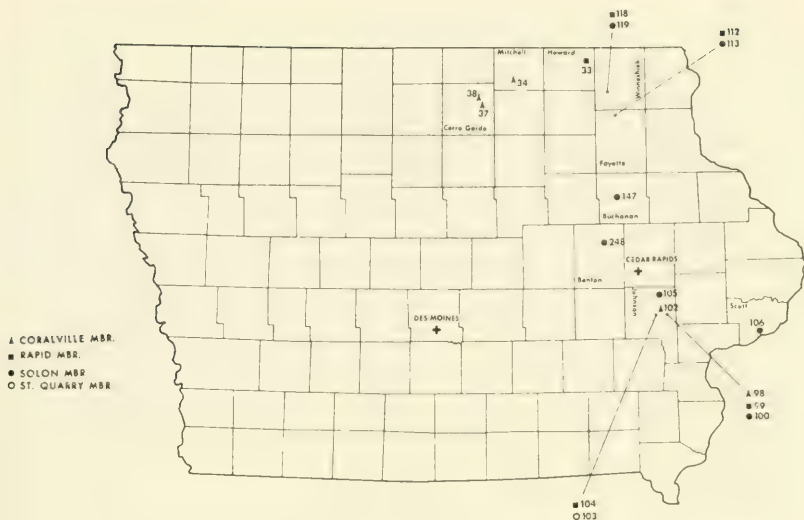
Variations in the vertical distribution of the Chitinozoa were noted, with some species showing a restriction to the respective members. On the basis of the species distribution, Dunn proposed that the assemblage of Collinson and Scott was characteristic of the Rapid Member and not the Solon Member as reported.

*P.O. Box 30365, Dallas, Texas 75230. Contribution No. 206.

DEVONIAN SYSTEM			
	Upper Devonian	Yellow Spring Group	English River Fm. Maple Mill Fm. Aplington Fm. Sheffield Fm.
			Lime Creek Fm.
			Shell Rock Fm.
	Middle Devonian		Owen Mbr. Cerro Gordo Mbr. Juniper Hill Mbr.
			Nora Mbr. Rock Grove Mbr. Mason City Mbr.
			Coralville Mbr. Rapid Mbr. Solon Mbr.
			Davenport Mbr. Kenwood Mbr. Otis Mbr. Coggen Mbr. Bertram Mbr.
	Lower Devonian		Laport City Fm.

Table 1. Stratigraphic section of the Devonian System of Iowa.

Subsequent to the study by Dunn, the River Products Quarry was deepened and the Solon Member of the Cedar Valley Formation plus the upper part of the Wapsipinicon Formation were exposed. Samples were taken from this and 13 other sections coincident with a more encompassing study of the palynology of the Devonian of Iowa and Missouri. The Chitinozoa that are the subject of this investigation were recovered from six of the fourteen sections that were sampled. The sample localities are located along the outcrop line in eastern Iowa (Text-fig. 1). Detailed geographic locations are given in Table 2.



Text-figure 1. — Location of sampled sections.

METHODS

The sampling and processing techniques were the same as described in Urban and Kline (1970). Five strew mount microscope slides were prepared of the residue from each sample interval using Clearcol for the mounting medium and the method of Wilson (1959). Individual specimens were prepared for examination with the scanning electron microscope using the procedures outlined in Urban and Padovani (1970).

Slides containing the type specimens have been deposited in the palynological repository of the University of Oklahoma, Norman, Oklahoma. The number sequences for type specimens refers to sample number, slide number, and ring number on the slide.

ACKNOWLEDGMENTS

Appreciation is expressed to Fred Dorheim, Chief of Economic Geology, Iowa Geologic Survey, and Don Koch, Chief of Subsurface Geology, Iowa Geologic Survey, for assistance with the field work and collecting of samples. Mary Parker, Chief of Geologic Research, Iowa Geologic Survey, Anton L. Hales, University of Texas at Dallas, Jocelyne Legault, University of Saskatchewan, and

TABLE 2

Location of Sample Localities

- SP 33. Barks Vernon Springs Quarry, Howard County, Iowa, near center, Sec. 28, T99N, R11W, Rapid Member, Cedar Valley Formation.
- SP 34. Falks Osage Quarry, Mitchell County, Iowa, NE 1/4, SW 1/4, Sec. 35, T98N, R17W, Coralville Member, Cedar Valley Formation.
- SP 38. Weaver's Quimby Quarry, Cerro Gordo County, Iowa, NW 1/4, NW 1/4, Sec. 27, T97N, R24W, Coralville Member, Cedar Valley Formation.
- SP 98. River Products Quarry, Johnson County, Iowa, NE 1/2, NW 1/4, Sec. 32, T80N, R6W, Coralville Member, Cedar Valley Formation.
- SP 99. River Products Quarry, Johnson County, Iowa, NW 1/2, NW 1/4, Sec. 32, T80N, R6W, Rapid Member, Cedar Valley Formation.
- SP 100. River Products Quarry, Johnson County, Iowa, NE 1/2, NW 1/4, Sec. 32, T80N, R6W, Solon Member, Cedar Valley Formation.
- SP 102. Corner Iowa Ave. and State Hwy. 218, Johnson County, Iowa, Sec. 9, T79N, R6W, Coralville Member, Cedar Valley Formation.
- SP 103. Outside Iowa City, Iowa, NW Cor., Sec. 4, T80N, R6W, St. Quarry Member, Cedar Valley Formation.
- SP 104. Outside Iowa City, Iowa, NW Cor., 1/4, Sec. 4, T80N, R6W, Rapid Member, Cedar Valley Formation.
- SP 105. Van Yourney Quarry, Johnson County, Iowa, SW 1/4, SE 1/4, Sec. 26, T81N, R6W, Solon Member, Cedar Valley Formation.
- SP 106. Linwood Quarry, Scott County, Iowa, SW 1/4, Sec. 13, T77N, R2E, Solon Member, Cedar Valley Formation.
- SP 112. Scott Quarry, Fayette County, Iowa, SE 1/4, SW 1/4, Sec. 2, T94N, R9W, Rapid Member, Cedar Valley Formation.
- SP 118. Spillville Quarry, Winneshiek County, Iowa, SE 1/4, Sec. 20, T97N, R9W, Rapid Member, Cedar Valley Formation.
- SP 119. Spillville Quarry, Winneshiek County, Iowa, SW 1/4, Sec. 18, T95N, R9W, Solon Member, Cedar Valley Formation.
- SP 121. McEachran Quarry, Cerro Gordo County, Iowa, SW 1/4, SW 1/4, NW 1/4, Sec. 20, T96N, R19W, Coralville Member, Cedar Valley Formation.
- SP 147. Brooks Quarry, S. side of hwy. 20, Buchanan County, Iowa, NE Cor. 3, NW Cor. 4, T88N, R9W, Solon Member, Cedar Valley Formation.

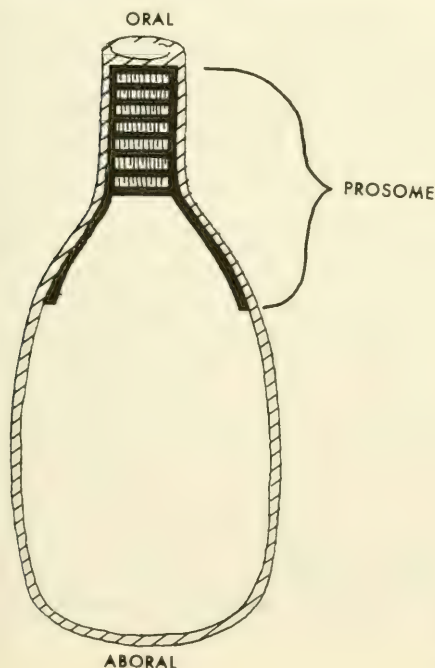
L. R. Wilson, University of Oklahoma, made constructive and appreciated criticisms of the manuscript. Special thanks are due Mrs. Denny Fagan for preparation and photography of the fossils with the scanning electron microscope and Miss Leah Waldorf for proof-reading the manuscript. Thanks also to The University of Texas at Dallas for financial support of this research.

PALEONTOLOGY

Thirteen species of Chitinozoa are reported in this study. Four of the species are considered to be new. Three of the new species are assigned to the genus *Desmochitina*, and one is assigned to the genus *Angochitina*. Detailed examination of some other specimens

with the scanning electron microscope indicates variations in morphology and preservation that necessitate a re-evaluation of their taxonomic assignment. Specifically, the morphologic variations observed in *Angochitina devonica* Eisenack are believed to encompass the circumscriptions of *A. milanensis* Collinson and Scott and *A. globosus* Collinson and Scott. In addition, *Ancyrochitina megastyla* Collinson and Scott and *Earlachitina latipes* Collinson and Scott appear to be the result of variations in *Ancyrochitina cornigera* Collinson and Scott due to preservational modifications.

Chitinozoa have been reported in the studies of the C.I.M.P. (Combaz, *et al*, 1967; Taugourdeau, *et al*, 1967) as having three layers (periderre, ectoderre, endoderre), but it was stated that the periderre was not frequently observed. Urban and Kline (1970) demonstrated that three layers are relatively common in some species of *Angochitina* and *Ancyrochitina*, the ornament being considered as the periderre. The specimens encountered in this study suggest that a similar situation exists for species of *Desmochitina*. This interpretation is contingent upon the operculum and the opisthosome being considered endoderre.



Text-figure 2. — Morphology of the prosome.

The periderre is a fragile, spongy layer and tends to be modified or destroyed readily. The modifications of the periderre are somewhat sequential, depending on the amount of degradational effects operating on the Chitinozoa wall. As a result of the modifications, the periderre in Chitinozoa appears as a series of different ornamentation types. Ultimately, the periderre is completely removed and only the smooth ectoderre remains. Consequently, taxonomic determinations must take into consideration possible degradational effects.

The prosome is an enigmatic structure of many Chitinozoa, of which the functional role is not understood. Removal of several prosomes from specimens of *Angochitina devonica* has provided some definitive information about the morphology of the structure. Two variations of the prosome are commonly observed in specimens assigned to *A. devonica* as well as many other species. One appears as a solid plug, while the other has been described as an "annulated tube" (Taugourdeau, *et al.*, 1967). Both types of prosomes show the basic structure to consist of an upper cylindrical tube and a lower carina-like flap (Pl. 2, figs. 8-10). The "annulated" type of prosome is partitioned by a variable number of circular discs that are unornamented on the oral surface and ornamented with fine spines on the aboral surface (Text-fig. 2, Pl. 2, figs. 11, 12). These fine spines extend down toward the next subjacent disc. The compact nature of the upper cylindrical tube plus the spines between the discs make it improbable that this structure was retractile as supposed by Jansonius (1964).

A plausible explanation of the function for the prosome is one of reproduction. Each disc may represent an embryonic stage from which a new individual develops. The discs could have been liberated directly or an individual might have developed while the disc was located in the neck. At the completion of the reproductive cycle any remaining part of the prosome might have been shed. Such an explanation might account for some sample intervals containing Chitinozoa in which almost all individuals are without the prosome, while the prosome is present in virtually all Chitinozoa from other sample intervals. The variation of the number of discs in the prosome of different individuals could be a result of the stage of the reproductive process. Occurrence of two types of prosomes in in-

dividuals that are otherwise virtually identical may also be related to the reproductive process. The solid prosome may represent the early stages of development or final degeneration before being shed.

Genus **ALPENACHITINA** Dunn and Miller, 1964

Type species. — *Alpenachitina eisenacki* Dunn and Miller, 1964.

Alpenachitina eisenacki Dunn and Miller, 1964 Pl. 1, fig. 1

1964. *Alpenachitina eisenacki* Dunn and Miller, pp. 725, 726, pl. 119, figs. 1-12.

Discussion. — This species was observed in a single sample but was not noted in the quantitative counts. Although some spines have been broken off, the two rows characteristic of the species are present. Some short, unbranched spines are present on the base of the specimen which were not mentioned in the original description and may represent a new species, but more specimens would be needed to evaluate the character.

Occurrence. — SP100B.

Genus **ANCYROCHITINA** Eisenack, 1955

Type species. — *Ancyrochitina ancyrea* (Eisenack), Eisenack, 1955.

Ancyrochitina cf. **A. spinosa** (Eisenack), Eisenack, 1955 Pl. 1, figs. 2, 3

1932. *Conochitina spinosa* Eisenack, p. 270, pl. 12, figs. 11-13.

1955. *Ancyrochitina spinosa* (Eisenack, 1932), Eisenack, p. 18, pl. 2, figs. 1, 2.

Discussion. — The original description of this species is general. Consequently, specimens possessing a variety of morphologic differences could be assigned to it. Two such differences have been seen in Chitinozoa from other formations. One group of specimens has the spines aligned in rows while another group appears to have them randomly distributed. Both types could readily fit the species description; however, the random spine distribution has been arbitrarily chosen to represent *A. spinosa* (Eisenack). A redescription of the type species would undoubtedly make the taxon more useful.

Occurrence. — SP105C; SP106C,D,E; SP100B,C,D,E,F,G.

Ancyrochitina aequoris Urban and Kline, 1970 Pl. 1, figs. 4-6

1970. *Ancyrochitina aequoris* Urban and Kline, p. 71, pl. 18, figs. 6-9, 15-17.

Discussion. — This species was originally described from the Cedar City Formation of Missouri which is at least partially

equivalent to the Cedar Valley Formation. The ornament commonly appears weblike, as seen in Plate 1, figure 5. Deterioration of the ornament leaves spines of various forms aligned in rows parallel to the axis.

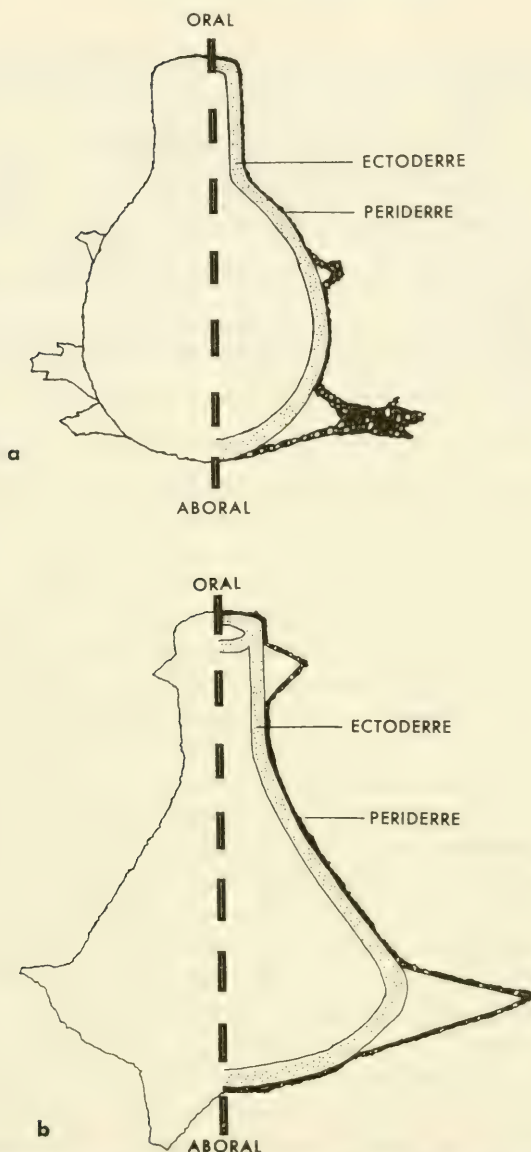
Occurrence. — SP100CG; SP106C,E.

Ancyrochitina cornigera Collinson and Scott, 1958 Pl. 1, figs. 7-12

1958. *Ancyrochitina cornigera* Collinson and Scott, pp. 18, 19, pl. 2, figs. 4, 5, 15-19.
 1958. *Ancyrochitina megastyla* Collinson and Scott, pp. 19, 20, pl. 2, figs. 1-3, 7.
 1958. *Earlachitina latipes* Collinson and Scott, pp. 25, 26, pl. 2, figs. 8, 9, 12-14; pl. 3, figs. 13, 24.
 1958. *Earlachitina* n. sp. Collinson and Scott, pp. 26, 27, pl. 2, figs. 6, 10, 11.

Discussion. — The original description of *Ancyrochitina cornigera* Collinson and Scott (1958, p. 18) stated “. . . the body cavity extends into the spines.” A similar statement is made in describing *A. megastyla* and *Earlachitina latipes*. Examination of several hundred specimens with the SEM and optical microscope indicates that the chamber does not extend into the spine. Instead, the spines are large hollow structures formed by an outer layer (periderris) and end blindly against the body chamber (Text-fig. 3a, Pl. 1, figs. 7, 8).

A. cornigera was originally distinguished by having “spike-like spines of circular cross section” whereas *A. megastyla* had “broad attenuate spines.” The specimens examined in this study indicate that the size and number of spines appear to be continuously variable. The spine length was observed to vary from 5 microns to 22 microns in length, and the number of spines from 4 to 12. The width of the base of the spines was also observed to vary from 2 microns to 10 microns. Forms with the broader spines are believed to be representative of what Collinson and Scott described as *A. megastyla*. Additional variation in form is related to the manner in which specimens may be compressed. Commonly, the body chambers tend to collapse and flatten parallel to a plane through the aboral edge. The spines which are on the aboral edge flatten in a similar manner and give the appearance of spines on the periphery of a brim. This latter form is believed to represent *Earlachitina latipes* Collinson and Scott. In addition, the three species have parallel occurrences. Consequently, they are all believed to be varia-



Text-figure 3. — Diagrammatic representation showing the relationship between the ornament, periderre, and ectoderre. a. *Angochitina devonica* type b. *Ancyrochitina cornigera* type.

tions of a single basic type. The holotypes of Collinson and Scott (1958) were not observed, but specimens from the type locality were studied. The specimens figured by Dunn (1959) were also studied.

Occurrence. — SP105E,G,H,I; SP106E; SP100B,C,D,F,G,I,J,K, L; SP99A,B,C,E,I.

Genus **ANGOCHITINA** Eisenack, 1931

Type species. — *Angochitina echinata* Eisenack, 1931.

Angochitina devonica Eisenack, 1955

Pl. 2, figs. 1-12

1955. *Angochitina devonica* Eisenack, p. 318, pl. 1, figs. 10-12.

1958. *Angochitina milanensis* Collinson and Scott, pp. 11, 13, pl. 1, figs. 1-5, 7, 8, 19, 26.

1958. *Angochitina globosa* Collinson and Scott, pl. 1, figs. 11, 13, 22, 23, 25.

1959. *Angochitina milanensis* Collinson and Scott, Dunn, p. 1011, pl. 125, figs. 17, 18, 20, 21.

1959. *Angochitina globosa* Collinson and Scott, Dunn, p. 1011, pl. 125, pp. 1011, 1012, pl. 126, figs. 22-25.

1961. *Angochitina* cf. *A. devonica* Eisenack, Staplin, p. 419, pl. 51, figs. 1-7.

Discussion. — Eisenack (1955, p. 316) described *A. devonica* with a neck length that is 40 percent to 50 percent of the total length, although a paratype (Pl. 1, fig. 12) has a neck length approximately 20 percent of the total length. Collinson and Scott (1958, pl. 12) used the statement of neck length as an important criterion in distinguishing *A. devonica*, *A. milanensis*, and *A. globosa*. They did state (p. 11) in comparing *A. milanensis* with *A. devonica* that “. . . as both species are variable, transitional forms may occur. . . .” In the remarks about *A. globosa* (p. 15) the writers stated “. . . *A. globosa* is variable so that a few specimens approach the shape of some variants of *Angochitina milanensis*. . . .” Several thousand specimens have been studied in this investigation and indicate that the neck length/overall length ratios and subtle shape variations are not suitable criteria for separating these three species.

In describing the species, Eisenack (1955) reported the ornament of the chamber as “. . . numerous, simple to well branched, partly antler-like and often bizarrely formed spines, which can be disproportionately broad at the base. . . .” The holotype and paratypes clearly indicate the occasional broad-based spines. SEM examination of Chitinozoa indicate that the broad-based spines occur commonly in forms that show a vertical alignment of the ornament on the chamber. The Chitinozoa of the Cedar Valley Formation which have been referred to the three species of *Angochitina* exhibit a vertical alignment of the ornament. In addition, the species have been reported with parallel occurrences. Therefore, the

gradational nature of the length ratios and shape variations plus the unifying characters of the ornament distribution and parallel stratigraphic occurrence suggest that *A. milanensis* and *A. globosa* are junior synonyms of *A. devonica* Eisenack.

Occurrence. — SP100B,C,D,E,F,G,H,I,J,K,L; SP99A,B,E,I; SP147B; SP106C,D,E,F; SP105A,B,C,E,F,G,H.

Angochitina capillata Eisenack, 1937

Pl. 3, fig. 8

1937. *Angochitina capillata* Eisenack, p. 359, pl. 15, figs. 12, 13.

Occurrence. — SP105E,H; SP106D,F; SP119C; SP100D,E,K,L.

Angochitina implicationis Urban, n. sp.

Pl. 3, figs. 1-7

Derivation of name. — *implicationis* L. — an entwining, interweaving. Referring to the tangled appearance of the tips of the spines.

Description. — Chitinozoa with a cylindro-spheroid to ovoid body form. Flexure is generally indistinct. The oral end is characterized as a circular opening inside a thin membranous collarette. A prosome is commonly present and extends from the top of the chamber into the neck. The wall is two layers thick. The inner layer (ectoderre) is relatively thick. The outer layer (periderre) is variable in thickness and is the layer from which the ornament is derived. Ornament consists of spines that are variable in form and distribution. Spines are short (10 microns on holotype) and most commonly bifurcate although single spines and multifurcate spines are present. The spines are commonly interconnected at their bases, forming rows parallel to the long axis. The rows may be broken up, leaving patches of spines distributed over the chamber and neck but still retaining a linear trend. Spines are reduced in length on the aboral end, neck, and collarette. Spines are hollow and end blindly against the ectoderre.

Size. — Holotype 144 microns long, chamber 84 microns wide.

Types. — Holotype; 106E1-1; paratypes, 106E2-2, 106E2-1.

Type locality. — Linwood Quarry, Scott County, Iowa, SW 1/4, Sec. 13, T77N, R21E, Solon Member, Cedar Valley Formation.

Occurrence. — SP100G,I; SP106D,E,F; SP105G,H.

Discussion. — This species is somewhat similar to *A. callawayensis* Urban and Kline, 1970. *A. callawayensis* has longer spines in

a definite linear arrangement. The spines of *A. implicationis* are connected at their bases but the spines on *A. callawayensis* are not. *A. capillata* is similar but the spines are not interconnected.

Genus **DESMOCHITINA** Eisenack, 1931

Type species. — *Desmochitina nodosa* Eisenack, 1931.

Discussion. — Laufeld (1967, p. 319) reviewed the taxonomic problems of the genus. As he pointed out, the emendation of Jansonius (1964) would restrict the genus in difference to concepts of the type species. Consequently, the diagnosis of Eisenack (1931) will be used, although it is recognized that a revision of the genus is needed.

Specimens of *Desmochitina* are commonly considered to have pores in the center of the base and in the operculum. Several hundred specimens were studied with the scanning electron microscope during this research and none of them were found to contain a pore at either end.

Desmochitina parkerae Urban, n. sp.

Pl. 5, figs. 1-12; Pl. 6, figs. 1-9; Pl. 8, figs. 10-12

Derivation of name. — Named in honor of Mary Parker, Chief of Geologic Research, Iowa Geologic Survey.

Description. — Chitinozoa with ovoid body form. Flexure is variable. Oral end characterized by a circular aperture bordered by a low, thin collarette. The collarette may be parallel to the longitudinal axis or may be strongly reflexed away. Diameter of the oral opening is 80-90 percent of the body diameter in uncompressed specimens. A terminal operculum is commonly present but may be detached. The outer margin of the operculum is thickened and projects in an aboral direction to the interior of the body as an internal rim. The center of the operculum is thickened and commonly raised. The operculum may exhibit concentric banding in transmitted light. Wall is commonly two layers thick, but the endoderre is occasionally represented by an opisthosome.

The periderre is thick and spongy, and exhibits considerable variation of appearance due to preservation and maceration. In ideal specimens the surface of the periderre appears rugate on the flanks and becomes verrucate at the flexure and onto the collarette. The periderre is absent in the center of the base in a circular area

and thickens toward the periboral edge. A dimple is commonly present in the center of the basal area, but there is no opening to the interior. The ectoderme is a solid homogeneous layer. An opisthosome may be present. The opisthosome originates from inside the periboral margin and projects in an oral direction approximately 50 percent of the body length. The opisthosome has the form of an inverted cone with the apex truncated and is ornamented with irregular, blunt protuberances scattered over the surface.

Chains have not been observed, but the absence of the periderme on the aboral end suggests a stacked arrangement.

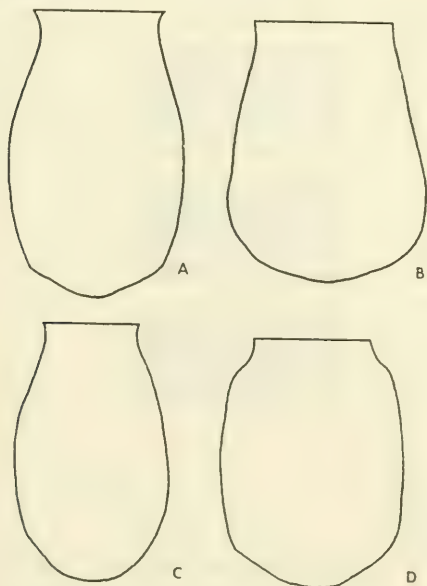
Size. — Holotype, 156 microns long, chamber width 101 microns.

Types. — Holotype, 100F30-1; Paratypes 100F23-1, 100F18-1, 100F-1, 100F30-2, 100F3-2, 100F10-1, 100C-1, 106D-1.

Type locality. — River Products Quarry, Johnson County, Iowa, NE 1/2, NW 1/4, Sec. 32, T80N, R6W, Solon Member, Cedar Valley Formation.

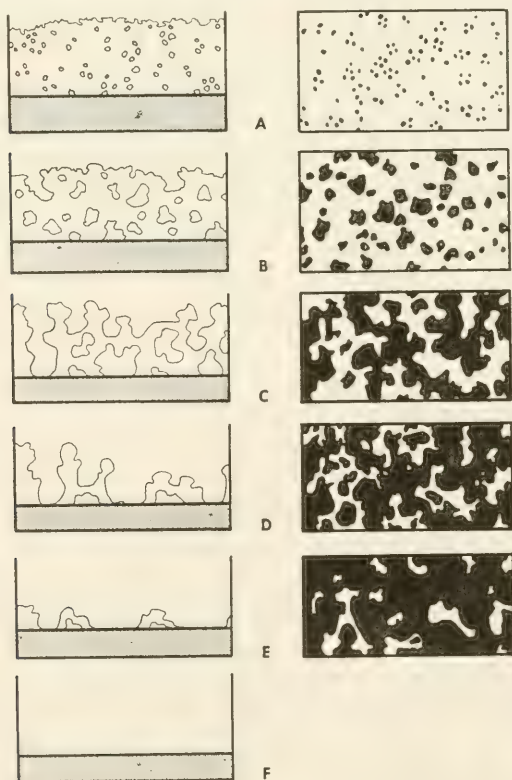
Occurrence. — SP100C,D,E,F,J; SP147B,C.

Discussion. — A considerable amount of variation of body form and ornamentation is present in this species. The variations of ornamentation seem to be primarily related to preservation and effects of maceration. It is recognized that other things may be responsible.



Text-figure 4.—Shape variations of *Desmochitina parkerae*.

Approximately four basic shapes can serve to demonstrate the range of variations (Text-fig. 4). The first would be as the holotype (Pl. 5, fig. 1, Text-fig. 4c) with a cylindrical body, a gently convex base, gently rounded shoulder with a definite flexure and a low collarete slightly reflexed from the longitudinal axis. Another variation is a form (Pl. 5, fig. 5, Text-fig. 5a) with fairly constant chamber width throughout the length. This variation trend culminates in a form with an enlarged aboral end (Pl. 5, fig. 7, Text-fig. 5b). There is no flexure, nor is the collarete distinguishable as a separate entity. A slight shape variation is illustrated by the specimen (Pl. 6, fig. 1, Text-fig. 5d) in which the greatest diameter is midway of the chamber and tapers gently both directions to the periaoral edge and to the flexure. A flexure is present, but the collarete is not reflexed away from the longitudinal axis.

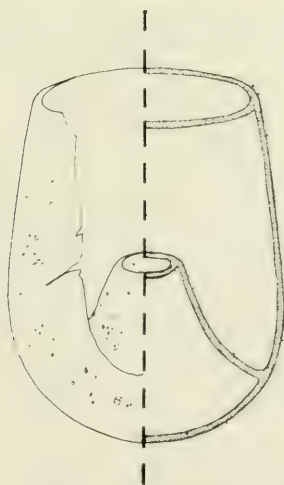


Text-figure 5. — Variations of ornament due to modifications of the periderme of *Desmochitina parkerae*.

Considerable variation in ornamentation exists and can be related to degradation of the periderre. Alteration of the periderre is shown diagrammatically in Text-fig. 5. The periderre begins as a porous, spongy structure (Text-fig. 5a). Early stages of degradation result in a surface (Text-fig. 5b) that is verrucate to rugate. Continued breakdown may channel beneath the rugae, forming loops (Text-fig. 5c). The loops may be interconnected and appear on the surface as an irregular reticulum (Text-fig. 5d). Separation of the loops results in ridges or rodlike protuberances (Text-fig. 5e). Finally, complete removal results in a smooth ectoderm (Text-fig. 5f).

The variations of shape present problems in taxonomy, particularly at the generic level. Jansonius (1964) established the genus *Eisenackitina* which was distinguished from *Desmochitina* by having straighter sides and the absence of a distinct flexure or collar. The variations observed in this species suggest that *Eisenackitina* is not clearly separable from *Desmochitina*.

The opisthosome has been reported only one time previously by Combaz and Poumot (1962). Some subsequent comments by other writers have suggested the structure originally described might be a result of an infolding of the base of the chamber. Obviously the structure shown (Pl. 6, figs. 8, 9, Text-fig. 6) is a discrete morphologic entity. It differs from the opisthosome originally described as a horizontal partition by being projected in an oral direction and having a circular opening toward the oral end. The function of this structure is not known but is suggestive of the habit of some of the specialized reproductive structures of colonial hydrozoan coelenterates.



Text-figure 6. — Diagrammatic representation of the opisthosome.

Desmochitina parkerae Urban, n. sp. may be a junior synonym of *Eisenackitina castor* Jansonius. *E. castor* is described as having a cuticle that is smooth, roughened, or verrucose, occasionally with a few small spines. Degradation of the periderre might result in any of those types of ornament. However, the shape variations of *D. parkerae* do include forms with a distinct flexure and collar.

***Desmochitina aranea* Urban, n. sp.**

Pl. 6, figs. 10-12; Pl. 7, figs. 1-12; Pl. 8, figs. 1-3, 8, 9

Derivation of name. — *aranea* L. — a spider . . . Referring to the appearance of the ornament.

Description. — Chitinozoa with an ovoid body form. Flexure present but poorly defined. Oral end characterized by a circular aperture bordered by a short, membranous collarette. The collarette may be parallel to the longitudinal axis or may be strongly reflexed away. Diameter of the oral opening is 50-75 percent of the greatest body diameter. An operculum is commonly present but may become detached. The outer margin of the operculum is slightly thickened and projects in an aboral direction to the interior of the body as an internal rim. The central area of the operculum is uniformly thin and commonly breaks through, leaving only the outer rim.

A basal callus is present and is variable in form and prominence. There is no pore through the basal callus to the interior. The wall has only been observed to have two layers exclusive of the operculum. The periderre is thin and closely appressed to the ectoderre. The periderre is free in strips and patches, giving rise to an ornament which consists predominantly of patches of loops. The patches consist of a number of bars radiating from a central point in a spider-like or crablike manner. The tips of the bars are attached and the remainder is free, forming multiple loops. Degradation of the periderre changes the loops to short verrucae. The ornament is coarsest on the periboral edge. Ornament is absent from the bottom of the basal callus and reduced to absent on the collarette.

Chains have not been observed, but the character of the basal callus and the operculum suggest that they may have been connected in a chain.

Size. — Holotype 137 microns long, chamber width 89 microns.

Types. — Holotype 100F23-2; Paratypes 100F-2, 100F-3, 100F23-3, 100B-1, 100E3-3, 100E3-4, 253A1-1, 100E3-1.

Occurrence. — SP100B,C,D,E,F; SP147B,C.

Discussion. — The body form is variable in this species but not to the extent of *Desmochitina parkerac*. The greatest amount of variation occurs in the ornament and prominence of the basal callus which may vary from a conspicuous basal protuberance to an inconspicuous inflection on the base.

This species differs from *D. parkerae* by the presence of a basal callus, a more consistent shape, and a different type of ornament. However, the periderre may be completely removed in both species, leaving a smooth ectoderre.

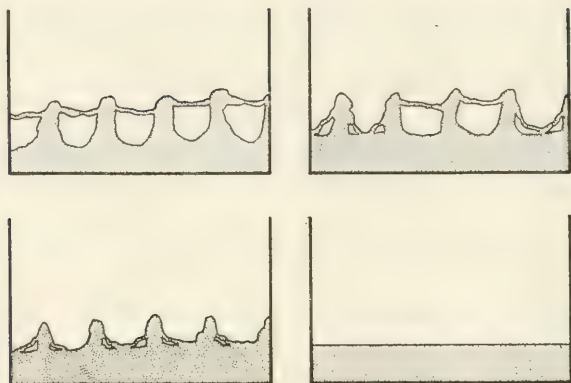
The modification of the periderre of *D. aranea* is shown diagrammatically in Text-figure 7.

***Desmochitina* sp.**

Pl. 8, figs. 4-7

Description. — Chitinozoa with a spheroid to ovoid body form. Flexure present but poorly defined. Oral end characterized by a circular aperture bordered by a short membranous collarete. Diameter of the oral opening is 60-70 percent of the greatest body diameter. An operculum is commonly present, but may become detached. Outer margin of the operculum is slightly thickened, and projects in an aboral direction to the interior of the body as an internal rim. The central area of the operculum commonly breaks through, leaving only the outer rim. An inconspicuous basal callus is present. The basal callus is formed by a ridge of periderre around a central basal depression. There is no pore through the basal callus to the interior. The wall has been observed to have only two layers. The periderre is spongy. Hollow rods protrude from the surface. Two adjacent rods commonly join to form an arch and continue as a single rod from their point of juncture. The rods are also commonly joined at their bases, giving rise to a ramose ridge-like pattern. The ornament is coarsest on the periaboral edge. Ornament is absent from the bottom of the basal callus and reduced to absent on the collarete.

Chains have not been observed but the character of the basal callus and the operculum suggest they may have been connected in chains by a copula.



Text-figure 7.—Variations of ornament due to modifications of the periderre of *Desmochitina aranea*.

Size.—111 microns, average of 5 specimens.

Figured specimens.—253A1-5, 253A1-3, 253A1-2.

Occurrence.—SP100C,F.

Discussion.—The basal callus is formed by a thickened ridge of periderre around a basal depression. The wall is thinned in the basal depression and commonly breaks through, but there is no interconnecting pore.

D. parkerae differs from *D. sp.* by having a more variable shape and a different type of ornament. *D. aranea* differs from *D. sp.* by having a smaller, more prominent basal callus and a different type of ornament.

Genus **HOEGISPHAERA** Staplin emend.

Type species.—*Hoegisphaera glabra* Staplin, 1961.

Emended description.—Chitinozoa with a discoid body form. Flexure is present but indistinct. Oral end characterized by a circular aperture bordered by a rim that stands in low relief above the flexure. A terminal operculum is commonly present but may be detached. The operculum often exhibits a concentric banding and a rim around the circumference. Body chamber wall is two layers thick. A distal carina, which may be reduced to extended, is present.

Discussion.—The emended description includes a carina which was not mentioned in the original description of Staplin (1961, pp. 419-420) or in the proposed emendation of Jansonius (1964, p. 913). However, the paratype of Staplin (1961, pl. 50, fig. 6) shows a dark ring parallel to and just inside the body outline. Scanning

electron microscope examination of forms with a similar appearance from the Cedar Valley Formation have shown the "ring" to be a reduced carina. Although chains of *Hoegisphaera* have not been observed, the banding of the operculum and the carina suggest that chains are to be expected. Wilson and Dolly (1964, p. 227) proposed an emendation of *Hoegisphaera* but did not note the carina. They did recognize the variability of the wall and related the variability to preservation or to maceration. More than 300 specimens of *Hoegisphaera glabra* Staplin were studied and the rim or collar around the aperture does not show a variability such as that noted in *Calpichitina scabiosa* Wilson and Hedlund or *Hoegisphaera bransoni* Wilson and Dolly. The wall of *Hoegisphaera glabra* is much thicker and rigid than either *C. scabiosa* or *H. bransoni*. Compressed specimens of *H. glabra* commonly have cracks around the margin, but *C. scabiosa* and *H. bransoni* exhibit folds that are randomly distributed throughout the body. In addition, *H. glabra* almost invariably exhibits an oral-aboral orientation, whereas *C. scabiosa* and *H. bransoni* do not seem to have an orientation preference. The orientation preference obviously relates to fundamental morphologic differences. As a result of these differences, it is believed that *C. scabiosa* Wilson and Hedlund and *H. bransoni* Wilson and Dolly should not be assigned to *Hoegisphaera*. Instead, the genus *Calpichitina* should be conserved or studied for possible synonymy with the genus *Desmochitina* as recognized by Jenkins (1970).

***Hoegisphaera glabra* Staplin 1961 emend.**

Pl. 4, figs. 4-12

1961. *Hoegisphaera glabra* Staplin, Paleontology, vol. 4, pt. 3, pp. 419-420, pl. 50, figs. 5-7.

Emended description.—Chitinozoa with a discoid body form. Flexure is present but indistinct. Oral end characterized by a circular aperture bordered by a rim that stands in low relief above the flexure. The diameter of oral opening is consistently close to 50 percent of the body diameter in uncompressed specimens. A terminal operculum is commonly present but may be detached. The operculum often exhibits concentric banding and a rim around the circumference. Body chamber wall is two layers thick and smooth. The outer layer is expressed as a reduced or extended carina around the aboral edge.

Size. — 98-135 microns in diameter, median 115 microns, 225 specimens measured.

Occurrence. — SP100B,C,D,G,I; SP99A,B,I; SP105G; SP106D; SP147B,C.

Discussion. — Wilson and Dolly (1964, p. 227) suggested that the smooth exterior of *Hoegisphaera* may be the result of alteration induced by the processing techniques. Examination of more than 300 specimens indicates that *H. glabra* is actually smooth. Other species of Chitinozoa present in the same samples have many delicate structures but in no instance was there any indication of additional sculpturing of *H. glabra*. The carina is variable in its presence. It evidently becomes detached readily or reduced so that it appears only as a dark ring in transmitted light.

Genus **MARGACHITINA** (Eisenack), Eisenack, 1968

Type species. — *Desmochitina margaritana* (Eisenack, 1937).

Margachitina sp.

Pl. 3, figs. 9-12

Description. — Chain-forming Chitinozoa with a cylindrospheroid to ovoid body form. The oral (?) end is covered by a domed operculum (?) that is continuous with the next higher individual. The chambers are continuous between the two (?) individuals. A prosome was not present in the described specimen. The wall is two layers thick. The outer layer (periderre) is variable in thickness and is the layer from which the ornament is derived. Ornament consists of simple spines that are aligned in rows parallel to the long axis. The rows continue across the boundaries from one individual to another. The spines are hollow and end blindly against the ectoderre.

Size. — Total length, 276 microns, maximum width 91 microns.

Figured specimen. — 106D3A-1.

Occurrence. — SP106D.

Discussion. — There is some difficulty in describing this specimen due to the problem of orientation. One individual in the chain does not have the flared end that is considered to be an operculum. Consequently, there is reason for doubt as to what constitutes the oral or aboral end.

Genus **SPHAEROCHITINA** Eisenack, 1955

Type species. — *Lagenochitina sphaerocephala* Eisenack, 1931.

Sphaerochitina pilosa Collinson and Scott, 1958 Pl. 4, figs. 1-3

1958. *Sphaerochitina pilosa* Collinson and Scott, p. 21, pl. 3, figs. 1-5.

Occurrence. — SP105H,I; SP106C; SP100C,D,E,H; SP99A,E,H.

PALEOECOLOGY

Whether Chitinozoa are planktonic or benthonic is a subject of unresolved debate among researchers. Kozłowski (1963) maintained that some species of *Cyathochitina* and *Parachitina* had a benthonic habit. Urban and Kline (1970) considered some species of *Angochitina* and *Ancyrochitina* from the Cedar City Formation of Missouri to be benthonic because of their restricted geographic and stratigraphic occurrence. It was suggested that such a definite facies control and narrow restriction was more indicative of a benthonic habit for Chitinozoa.

Cramer (1970, p. 1123) mentioned a lateral and vertical restriction of some Ordovician Chitinozoa from the Sylvan Shale of southern Oklahoma. He speculated on the distribution being explained as a bloom phenomenon which is common among the dinoflagellates and the chlorophyte algae. Various investigators have supported the idea of Chitinozoa being planktonic due to their occurrence in many types of sedimentary rocks. While this observation does indicate that the fossils may occur in different types of sediment, it does not necessarily provide any definitive information concerning the paleoecology of the organisms. The presence of Chitinozoa in clastic sediment should be particularly suspect because of the size of the organism and its behavior as a clastic particle.

The hydraulic equivalency of some Chitinozoa from the Cedar Valley Formation was determined to facilitate a better understanding of their behavior as a clastic particle. The gravity settling method discussed by Twenhofel (1939, pp. 196-198) was used. According to this method, the Chitinozoa are associated with particles of diameters ranging from .0078 mm to .0156 mm. Therefore these Chitinozoa are fine silt particles and the sedimentologic association of Chitinozoa by transporting and depositing should be with siltstone and shale size fractions. The presence of fine-grained clastics

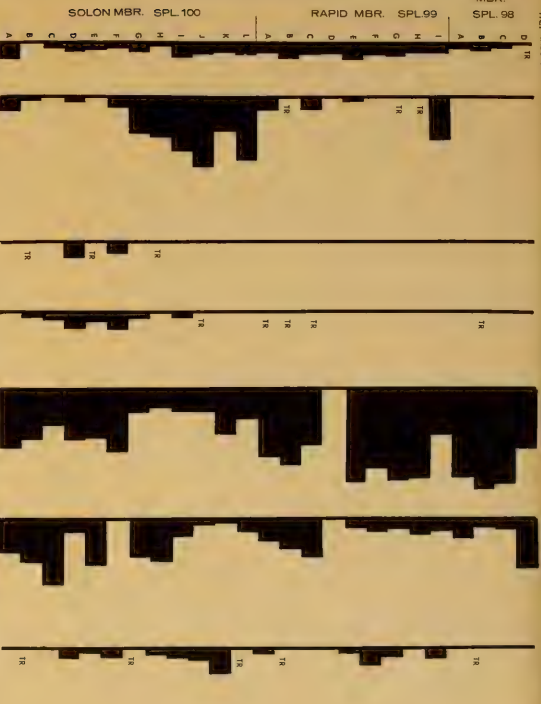
can be explained as a sedimentologic phenomenon, but it is recognized that other explanations are available. Taugourdeau and Jek-howsky (1960, p. 1207) demonstrated a similar situation with Chitinozoa from the Sahara. Volumetric determinations showed Chitinozoa to be most abundant in silts and shales.

Jenkins (1970, p. 12) mentioned a section of alternating black shales and volcanic ashes studied in the Llanvirn of Shropshire, England, in which the black shales contain an abundance of Chitinozoa and the volcanic ash layers are barren. It was also noted that the lower parts of the shale layers were similarly impoverished. This investigator suggests that the observations have considerable ecological significance. Innumerable instances are present in the literature of fossil spores and pollen, planktonic Foraminifera, radiolarians or nannofossils occurring in volcanic ash. If Chitinozoa are planktonic organisms, they should be found in the volcanic ash. However, if the Chitinozoa are related to a benthonic habitat and particularly a burrowing organism, an ashfall could be expected to wipe out a bottom dwelling community and an organic-rich substrate would have to be reestablished before the niche would be available for reestablishment of the organisms. Hence the impoverished lower intervals of the shale.

DISCUSSION

Fourteen sections of the Cedar Valley Formation have been studied in relation to this investigation. Seven of the sections contained Chitinozoa (Text-fig. 2), but one of those (SP113) had only a single specimen. Two other sections (Brooks Quarry — SP 147 and Pavlovec's Spillville Quarry — SP 119) had some peculiarities: In the Brooks Quarry samples, the majority of the specimens were broken, and all occurred near the lower 6 feet of the formation. The rest was barren. The Spillville Quarry samples yielded Chitinozoa in a single 2-foot interval and only the species *Angochitina capillata* was present.

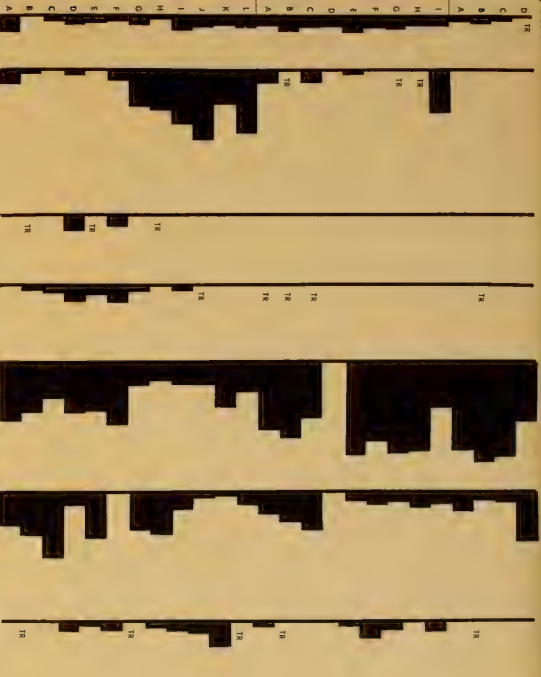
In the other four sections, greater diversity of species and overall number of Chitinozoa were observed. Detailed counts of the palynomorph assemblages and HCl-insoluble residues were made on samples from River Products Quarry (SP 98, 99, 100), Van Journey Quarry (SP 105), Linwood Quarry (SP 106), Vinton Quarry (SP

CORALVILLE
MBR.
SPL. 98

RIVER PRODUCTS QUARRY

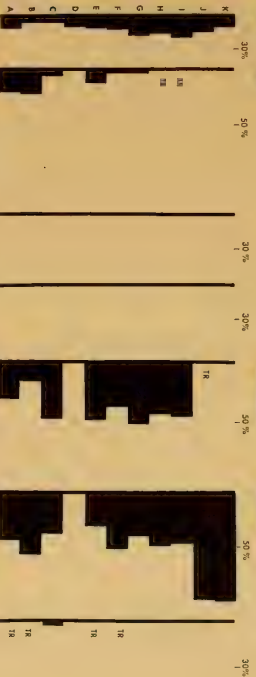
SOLON MBR. SPL 100

RAPID MBR. SPL.99



VAN YOURNEY QUARRY

SOLON MBR. SPL 105



LINWOOD QUARRY

SOLON MBR. SPL 106



VINTON QUARRY

SOLON MBR. SPL. 248

SCALE
0 30 50%LINDOCHITIN, ACHROCHITIN, AURIOCHITIN, and GRANOCHITIN
DESMOCHITIN and INOCHITINTEXT-FIGURE 8— HCl insoluble residue percentages
and palynomorph frequency distribution.

248). Insoluble residue percentages and palynomorph distribution in the above-mentioned samples are shown in Text-figure 8.

Palynomorph assemblages of *Desmochitina* were counted separately, because they evidenced a more restricted stratigraphic distribution. Comparison of the palynomorph assemblages with the insoluble residues indicated no positive correlation. There was, however, a significant correlation between *Desmochitina* and *Tasmanites*. In the lower part of the Solon Member of the Cedar Valley Formation at the River Products Quarry (SP 100), *Tasmanites* and *Desmochitina* were well preserved and showed similarities in their stratigraphic distribution and relative abundance, as was the case in the Vinton Quarry (SP 248) samples. The other section (Brooks Quarry, SP 147) that showed *Desmochitina* (fragment only) also showed *Tasmanites*. Since *Tasmanites* is believed to be a chlorophyte algae, this may indicate that the life zone of the *Desmochitina* in the Cedar Valley Formation was one of low turbidity.

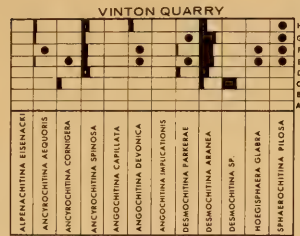
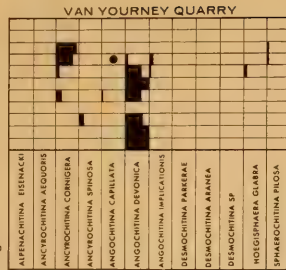
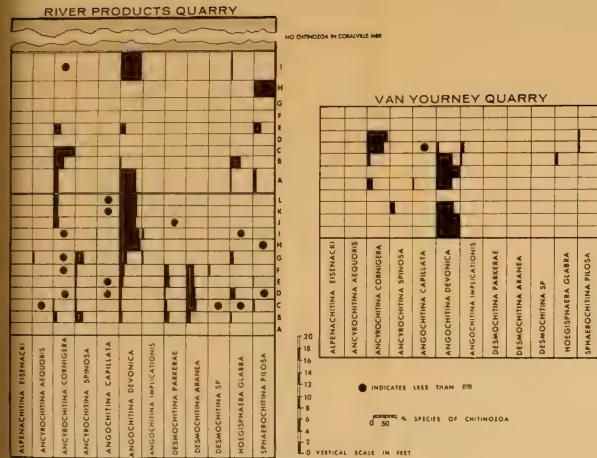
It is significant that the *Desmochitina* occurred exclusively in the three sections discussed above, while a section considered to be the Solon Member on the basis of lithologic and megafaunal evidence, taken approximately 10 miles north of the River Products section (105 A-J), had no *Desmochitina* despite the presence of other typical Cedar Valley Chitinozoa. However, the chitinozoan assemblage of locality SP 105 closely resembles the assemblage from the upper Solon and Rapid Member of SP 100 and 99 (Text-fig. 9). Consequently, the Solon at locality SP 105 may represent a lithofacies that is younger in age than that at SP 100 and SP 99. The subjacent Wapsipinicon Formation has also been examined at seven localities and the *Desmochitina* have not been recovered from the lower stratigraphic interval in the area. The distribution strongly indicates a marked vertical and lateral restriction of the *Desmochitina*. A particularly curious aspect of the Cedar Valley chitinozoan distribution is the absence of any type of Chitinozoa in the Coralville Member at all localities, although spores and acritarchs are abundant.

Dunn (1959, p. 1006) suggested that the distribution of Chitinozoa within the Cedar Valley Formation could be used to differentiate its members. He believed that *Ancyrochitina spinosa* (Eisenack) was diagnostic of the Solon Member, while *Ancyrochi-*

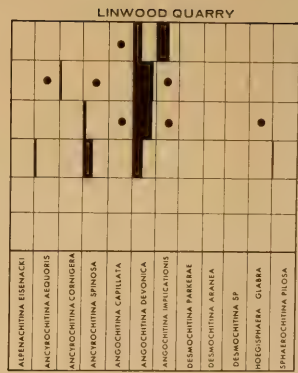
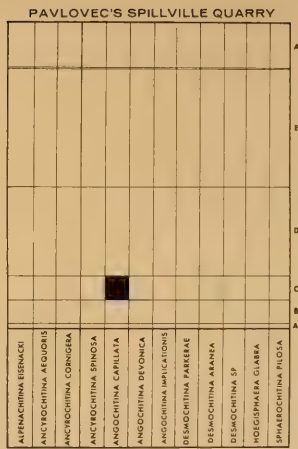
tina cornigera Collinson and Scott was diagnostic of the Rapid Member. On the basis of chitinozoan distribution he also suggested that the section studied by Collinson and Scott (1958) was the Rapid Member instead of the Solon Member.

The distribution of Chitinozoa as studied in several sections of the Cedar Valley indicated that the occurrence of Chitinozoa as well as the stratigraphy of the Cedar Valley is more complex than previously thought, and it demonstrates the difficulty of piecing together stratigraphic sections from different localities. Dunn's composite section clearly does not represent the Cedar Valley Formation adequately. This is demonstrated by the fact that the assemblage of *Desmochitina* was not recovered from Dunn's section. In addition, the distribution of chitinozoan species studied here does not support his contention. In SP 100 and SP 106 *Ancyrochitina cornigera* occurred together, as they did in SP 248, although in SP 248 *A. cornigera* was present in less than 1 percent of one sample. The only Chitinozoa which presently appear to show a limited stratigraphic distribution (Text-fig. 9) are the *Desmochitina* which occur in the lower 12 feet of the River Products Quarry, the lower 16 feet in Vinton Quarry, and the lower six feet in the Brooks Quarry samples. *Desmochitina aranea* was the most abundant, and its occurrence defines an assemblage zone which is hereby designated as the *D. aranea* assemblage zone. Other species occurring in this assemblage zone but not necessarily restricted to it are *Ancyrochitina aequoris*, *A. cornigera*, *A. spinosa*, *Angochitina capillata*, *A. devonica*, *Hoegisphaera glabra*, and *Sphaerochitina pilosa*.

The presence of the *Desmochitina aranea* assemblage zone at the base of some sections of the Cedar Valley Formation and its absence at others can be explained three possible ways: (1) Stratigraphy — The base of the formation is not contemporaneous throughout this region of Iowa, and the assemblage zone is included in the subjacent Wapsipinicon Formation. However, the Wapsipinicon has been studied at the Linwood (SP 106) and Scott (SP 114) Quarries and the *D. aranea* assemblage zone is not present. The Linwood Quarry contains an assemblage of Chitinozoa similar to the one described by Collinson and Scott (1958), while the Scott Quarry samples are devoid of Chitinozoa; (2) Facies control — The fact that their occurrence seems to be restricted to



TEXT-FIGURE 9— Frequency distribution of chitinozoan species



three localities approximately in the center of the area studied would support the contention that restricted biofacies are responsible for their presence; (3) Diagenesis — The boundary between the Wapsipinicon and the Cedar Valley Formation is commonly defined on the basis of a brecciated interval. The brecciated interval is believed to be a result of the solution and subsequent collapse of the lower part of the Cedar Valley Formation, so it is possible that the absence of the *D. aranea* zone at the base of the Cedar Valley Formation may be attributed to that phenomenon. However, the presence of the assemblage zone cannot be directly related to an increased thickness of the formation.

Ancyrochitina aequoris has been previously reported only from the Cedar City Formation of Missouri (Urban and Kline, 1970). This species is present in three sections of the Cedar Valley Formation and appears to be restricted to the lower part of the formation — approximately the *D. aranea* assemblage zone, though it is present in the Linwood Quarry section in an interval that appears to be somewhat higher stratigraphically.

The age of the Cedar Valley Formation is considered to span the Givetian-Frasnian boundary. Klapper and Ziegler (1967) have reported the conodont species *Icriodus latericrescens latericrescens*, *I. nodosus*, *I. obliquimarginatus*, *Polygnathus linguiformis*, *P. decorosa*, and *P. varca* from the Solon Member. All indicate correlation with the upper Hamilton Group of New York and a late Middle Devonian age.

The genus *Desmochitina* has not been found in rocks younger than Givetian which would support the designation of the *D. aranea* assemblage zone as Givetian. However, *Hoegisphaera glabra* has not been previously found in rocks older than Frasnian. Since the three desmochitinid species appear concurrently with *H. glabra*, the ranges of the *Desmochitina* must be revised upward or that of *Hoegisphaera* downward.

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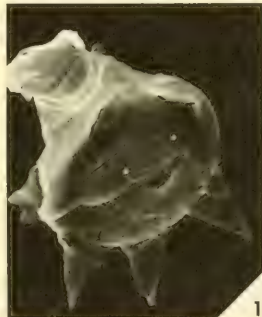
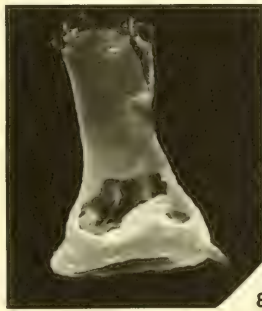
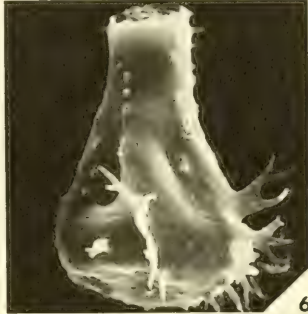
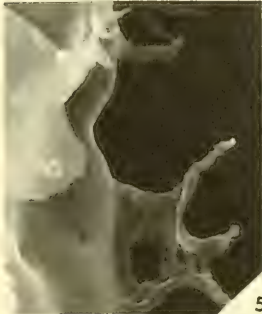
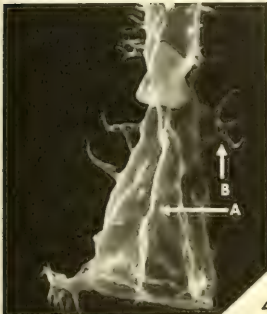
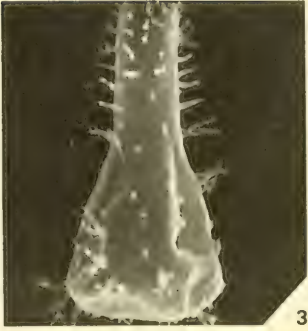
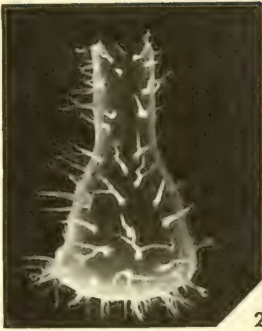
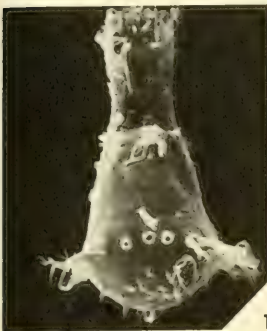
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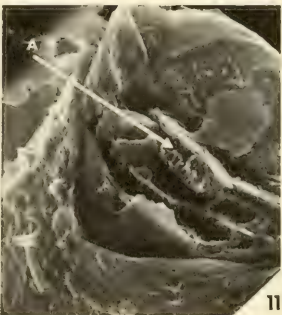
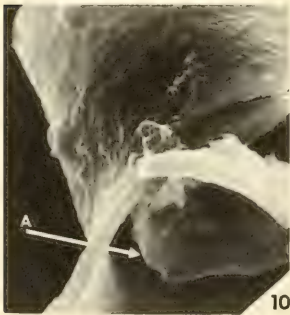
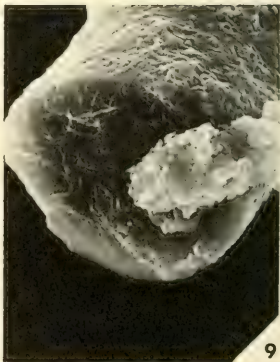
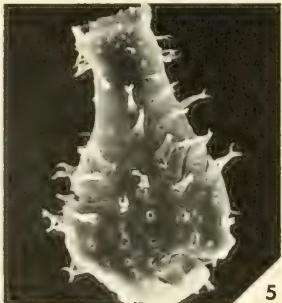
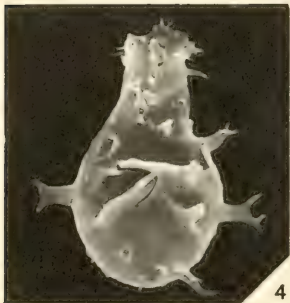
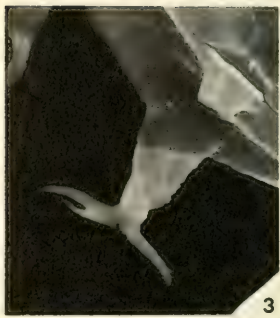
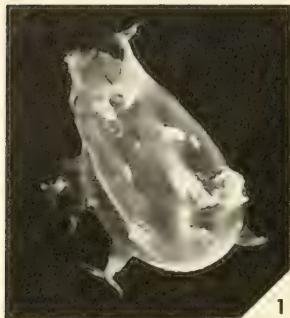
All scanning electron micrographs were taken at magnifications 2.5 times the indicated values. The plates were reduced to 40 percent of their size for publication.

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All figures are scanning electron micrographs.

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2, 3.	Ancyrochitina cf. A. spinosa (Eisenack), Eisenack, 1955	11
	2. Note the random arrangement of the spines over the entire form, $\times 220$. 3. $\times 240$.	
4-6.	Ancyrochitina aequoris Urban and Kline, 1970	11
	4. Note the spines aligned on the fold (A) and the spine at B, $\times 220$. 5. High magnification of spine on specimen in figure 4. Note the deterioration of the broad spine resulting in long thin spines, $\times 600$. 6. $\times 280$.	
7-12.	Ancyrochitina cornigera Collinson and Scott	12
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EXPLANATION OF PLATE 2

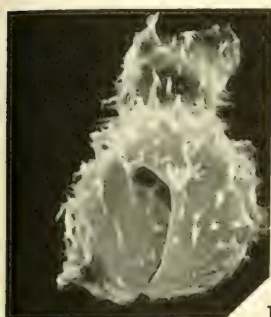
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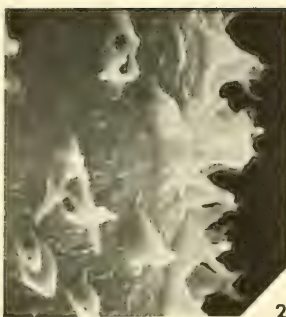
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All figures are scanning electron micrographs.

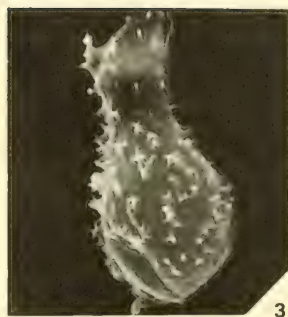
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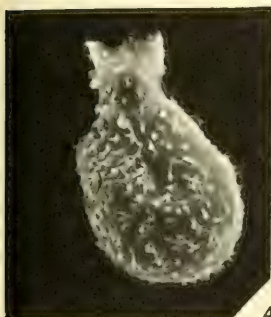
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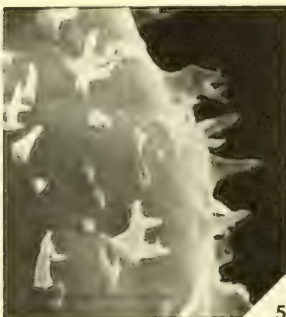
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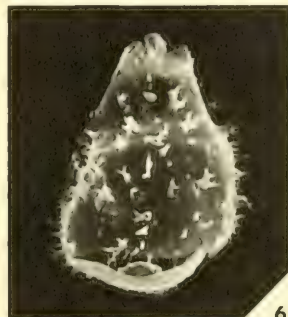
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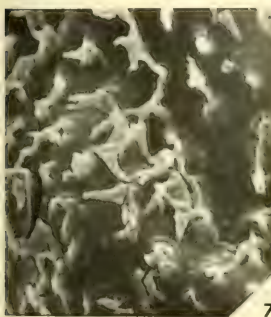
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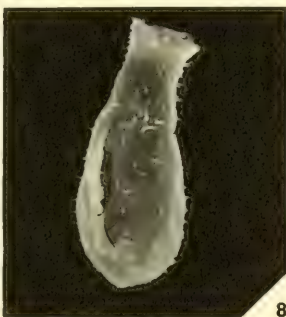
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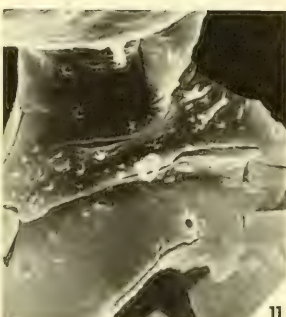
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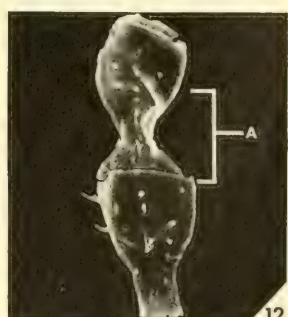
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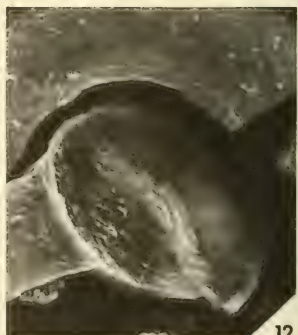
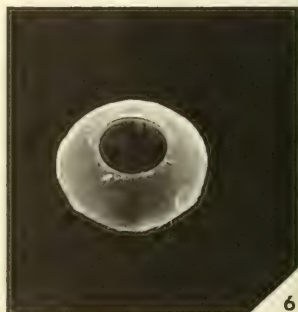
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EXPLANATION OF PLATE 4

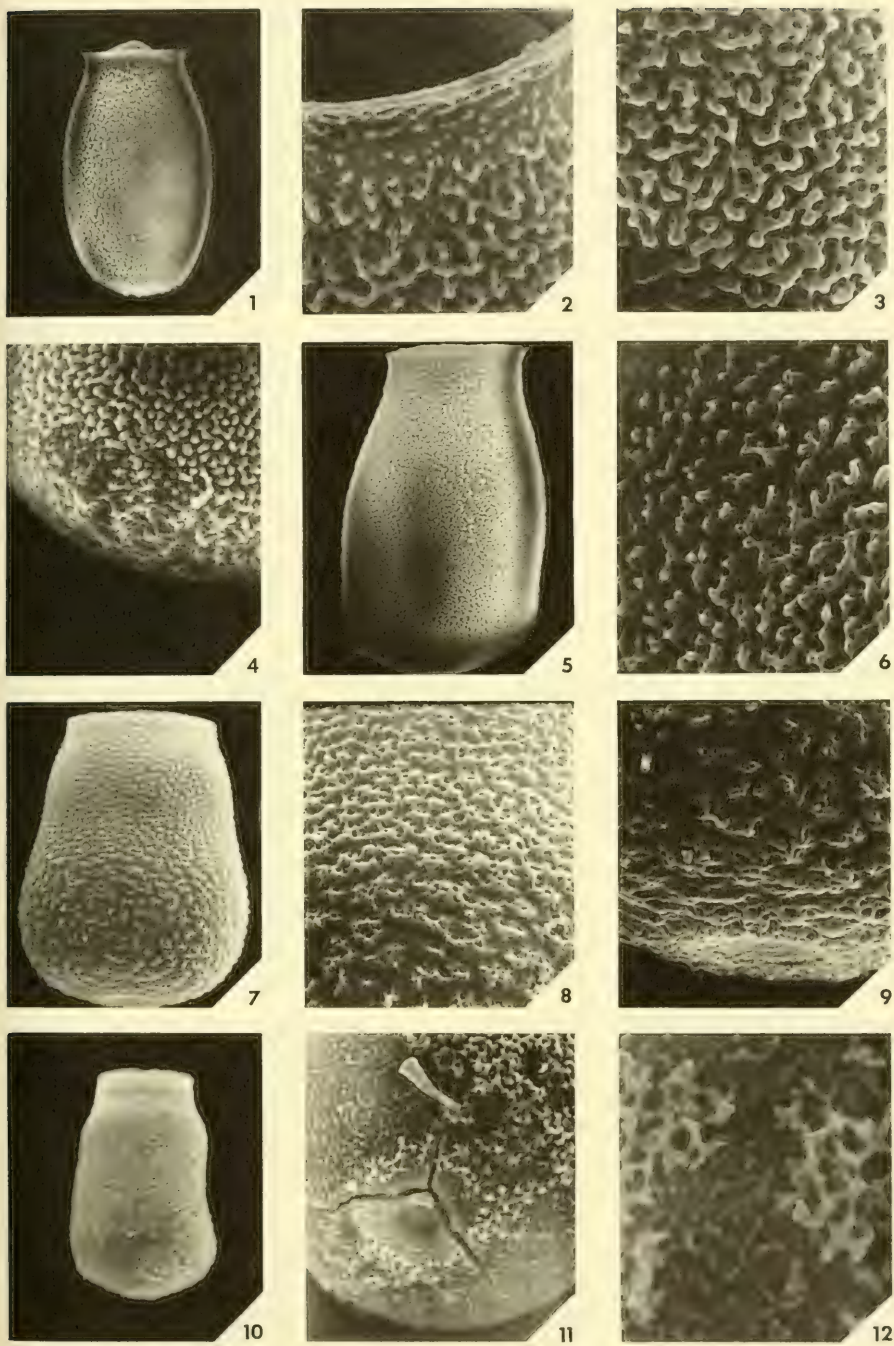
All figures are scanning electron micrographs.

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EXPLANATION OF PLATE 5

All figures are scanning electron micrographs.

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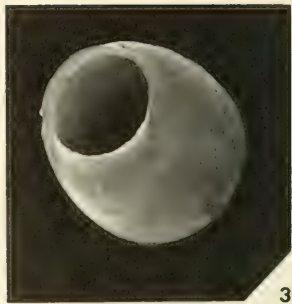




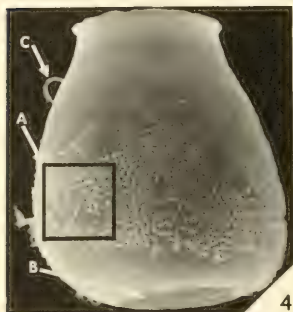
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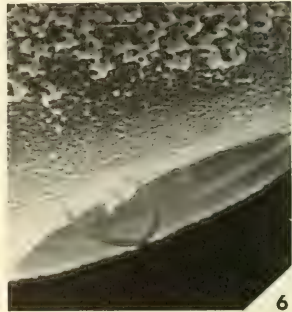
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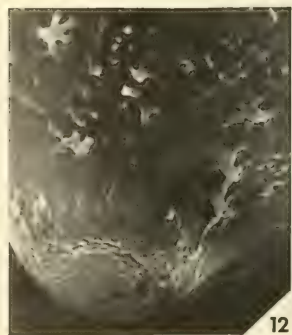
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EXPLANATION OF PLATE 6

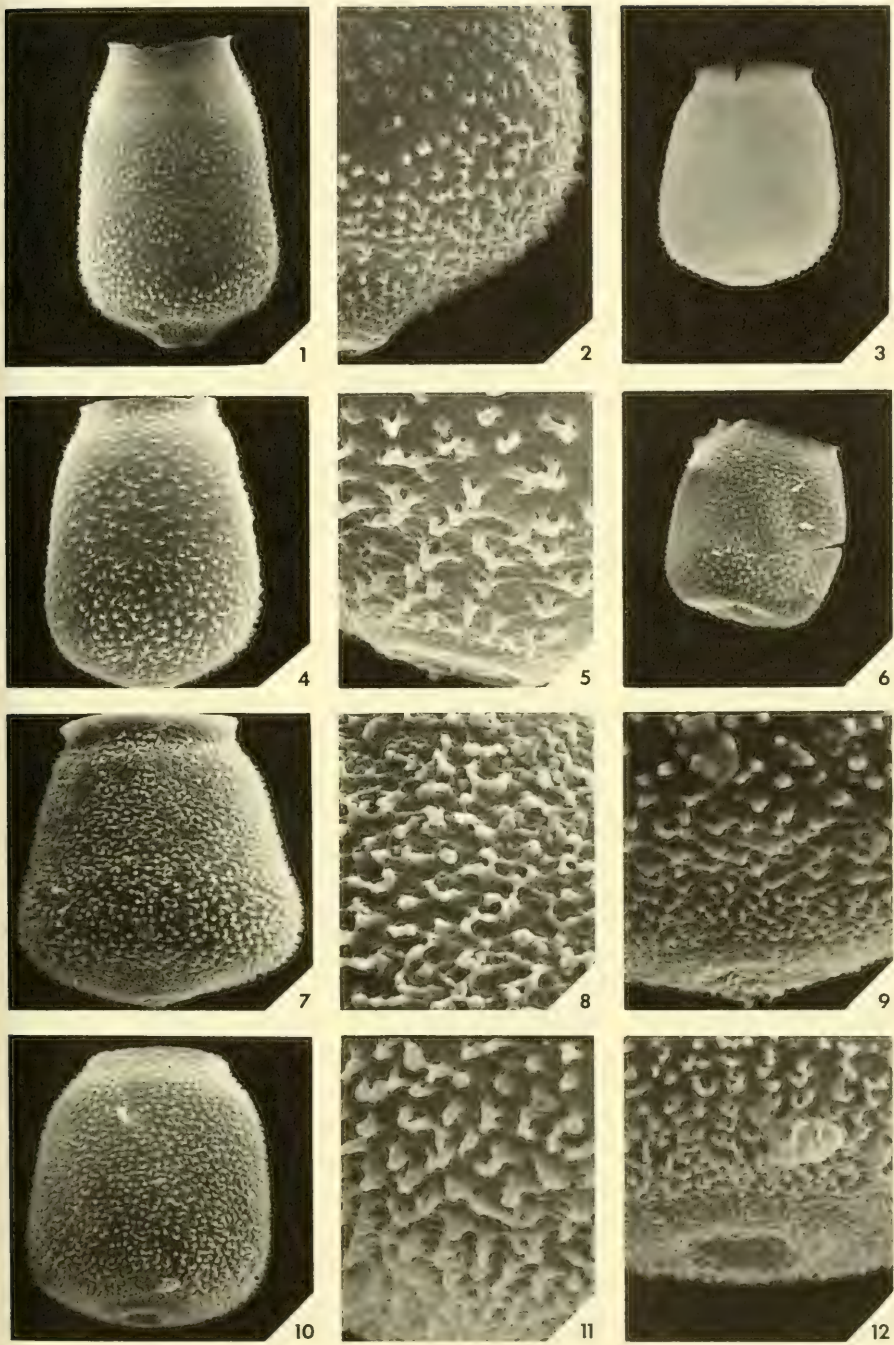
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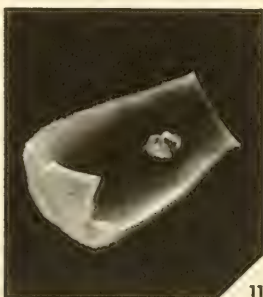
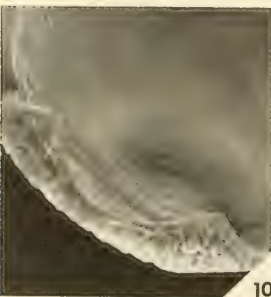
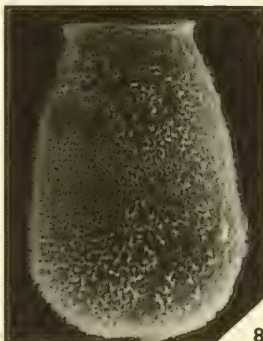
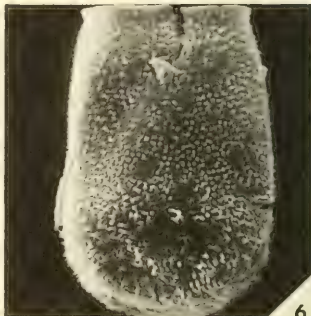
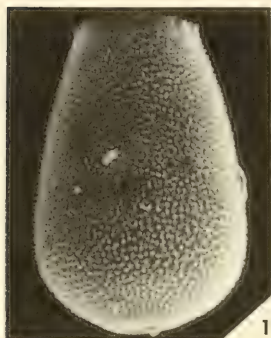
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All figures are scanning electron micrographs.

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UPPER CRETACEOUS SPUMELLARIINA FROM THE
GREAT VALLEY SEQUENCE,
CALIFORNIA COAST RANGES

By

EMILE A. PESSAGNO, JR.

1973

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Ithaca, New York 14850 U. S. A.

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February 16, 1973

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UPPER CRETACEOUS SPUMELLARIINA FROM THE GREAT VALLEY SEQUENCE, CALIFORNIA COAST RANGES*

EMILE A. PESSAGNO, JR.

ABSTRACT

Twenty new species and five new genera of Upper Cretaceous Spumellariina are described from the Archaeospongoprunicinae, new subfamily, the Obiculiformidae, new family, the Cavaspongidae, new family, and the Druppulidae Haeckel. One new species assignable to the Druppulidae is described from the Jurassic (Tithonian) of the Blake-Bahama Basin (Site 5A, DSD Leg 1).

The Archaeospongoprunicinae, new subfamily, include Pseudoaulophacilae with ellipsoidal spongy tests and bipolar spines. The Obiculiformidae include Pseudoaulophacilae with spongy, disc-shaped tests with irregular polygonal pore frames.

Spongodiscacea with spongy cortical shells enclosing latticed medullary shells are placed in the Spongodruppilae Haeckel. The Cavaspongidae, new family, are included in the Spongodruppilae.

INTRODUCTION

This is the seventh in a series of reports dealing with the Cretaceous Radiolaria of the Great Valley Sequence (cf. Pessagno, 1969, 1970, 1971a, 1971b, 1971c, 1971d). It deals primarily with Spumellariina that are important in developing a detailed system of zonation for the California Upper Cretaceous.

Pessagno (1971a, pp. 16-19) included all Spumellariina with spongy tests lacking sieve plates, lattice shells, and chambered rays in the Spongodiscacea Haeckel. In the present report this definition is emended somewhat to include forms having a spongy cortical shell and latticed medullary shell(s). These latter forms are included in the Spongodruppilae Haeckel.

A key to the classification of the Spongodiscacea at the superfamily and subsuperfamily levels is shown in Table 1.

ACKNOWLEDGMENTS

This work has been supported by grants from the National Science Foundation: GA-4043 to the University of California at Davis; GA-1224 to the S.W. Center for Advanced Studies, Dallas, Texas; GA-15998, GA-25712 to the University of Texas at Dallas and by the general NASA grant (NGL-44-044-011) to the S.W. Center for Advanced Studies.

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*Contribution Number 195, Geosciences Division, University of Texas at Dallas, P.O. Box 30365, Dallas, Texas 75230

Numerous megafossils were kindly identified for the writer by David L. Jones, Paleontology and Stratigraphy Branch, U.S. Geological Survey, Menlo Park, California.

TABLE 1

KEY TO THE CLASSIFICATION OF THE SPONGODISCACEA

Superfamily **SPONGODISCACEA** Haeckel

Presence of a spongy test of variable shape with or without latticed medullary shells and lacking sieve plates and chambered rays. Polygonal pore frames of spongy meshwork arranged with or without symmetry.

Subsuperfamily **SPONGODISCILAE** Haeckel

Spongodiscacea with irregular spongy meshwork with no symmetrical arrangement of pore frames. Overall test shape varying with family or subfamily.

Subsuperfamily **PSEUDOAULOPHACILAE** Riedel

Spongodiscacea with spongy meshwork comprised of pore frames arranged symmetrically in concentric rings, spirals, parallel layers, and so forth. Overall test shape varying with family or subfamily.

Subsuperfamily **SPONGODRUPPILAE** Haeckel

Spongodiscacea with layered spongy cortical shell enclosing latticed medullary shell(s).

NOTATIONS ON THE INTEGRATION OF RADIOLARIAN RANGE ZONES WITH PLANKTONIC FORAMINIFERAL ZONATION

(1) *Rotalipora evoluta datum* (first appearance). — Corresponds to base of *R. evoluta* Subzone (Pessagno, 1967, 1969a) which in turn corresponds approximately to the lower part of the *Mantelliceras mantelli* Zone of ammonite workers; earliest Cenomanian.

(2) First appearance of double-keeled *Globigerinacea*. — Corresponds to base of *M. sigali* Subzone (Pessagno, *ibid.*) and to base of *Actinocama plenus* Subzone in the Anglo-Parisian Basin (Jefferies, 1961, p. 618, pl. 79, fig. 30a-c). Jefferies considered the *A. plenus* Subzone early Turonian. (See discussion of Cenomanian—Turonian boundary problem in Pessagno, 1969a).

(3) *Globotruncana arca datum* (first appearance).— Corresponds to base of *G. fornicata*—*stuartiformis* Assemblage Zone (Pessagno, *ibid.*); basal Campanian. See Pessagno (1969a) for integration of megafossil and planktonic foraminiferal data and for discussion of Santonian — Campanian boundary problem.

(4) *Globotruncana hilli datum* (first appearance).— Corresponds to base of *G. calcarata* Zonule of Pessagno (*ibid.*) and to base of *Bostrychoceras polyplocum* Zone of ammonite workers latest Campanian. See Pessagno (1969a) for a more detailed discussion.

(5) *Globotruncana linneiana datum* (extinction).— Corresponds to the top of the *G. fornicata*—*stuartiformis* Assemblage Zone of Pessagno (*ibid.*); latest early Maestrichtian. No precise data available for the integration of planktonic foraminiferal and megafossil zonation.

LOCALITY DESCRIPTIONS

Locality descriptions are given below for all type localities and for all localities not described by the writer in previous papers on the Upper Cretaceous Radiolaria of the Great Valley Sequence (Pessagno 1969b, 1971a, b, c, d).

NSF 32-B. Lower part of the Forbes Formation ("Dobbins Shale" Member); 15 feet above contact between Forbes Formation and the underlying Guinda Formation. Gray calcareous mudstone with abundant limestone nodules; sample from limestone nodules. Tributary to Petroleum Creek, Yolo County, California, USGS Rumsey Quad. (7.5'). T12N; R3W; Section 10. 1.5 miles N43°W of VABM Guinda 1798. This locality occurs at about the same horizon as *NSF 134-B*. See planktonic foraminiferal data from *NSF 134-B* and planktonic foraminiferal and megafossil data presented under *NSF 55-B* (Pessagno, 1971a, p. 9); early Campanian.

NSF 134-B. See Pessagno, 1971a, p. 9.

NSF 207. Funks Formation (cf. Emerson and Roberts, 1962, *ibid.*) Gray calcareous to siliceous mudstones and siltstones with minor interbedded thin sandstones. Sample from gray mudstones containing abundant Radiolaria, rare planktonic Foraminifera, and common benthonic Foraminifera; Santonian. Upper portion of Funks; 10 feet below contact between Funks and overlying Guinda Formation. Bray Canyon. USGS Monticello Dam Quad. (7.5'); R2W; T8N; Section 21 (eastern edge).

Douglas (1969, p. 162) recorded *Hastigerinoides alexanderi* (Cushman) from the middle portion of the Funks at Bray Canyon. In Texas extensive sampling indicates that this species is restricted to the early Santonian *Marginotruncana concavata* Subzone. Other planktonic Foraminifera occurring in the lower and middle portions of the Funks at Bray Canyon include *Marginotruncana pseudolinneiana* Pessagno, *M. canaliculata* (Reuss), *M. augusticarinata* (Gandolfi), and *M. marginata* (Reuss). Jones (1966, pp. 199-203) recorded *Protexanites thompsoni* Jones from the Funks at Bray Canyon at a horizon situated several hundred feet above the base of the Funks. Jones (*ibid.*, p. 202) stated that *P. thompsoni* is indicative of either the late Coniacian or early Santonian.

NSF 227. See Pessagno (1971d, p. 292).

NSF 283. Yolo Formation (middle part of type Yolo at north bank of Cache Creek, Yolo County). Limestone nodules with dark gray calcareous mudstones and siltstones both containing abundant Radiolaria; 470 feet below the contact between the Yolo Formation with the overlying Sites Formation. USGS Glascock Mountain Quadrangle (7.5'); T12N; R4W; Section 2; 200 feet downstream from northwest end of Rt. 16 bridge over Cache Creek. Coniacian planktonic Foraminifera recovered from calcareous mudstones at this horizon include *Marginotruncana canaliculata* (Reuss) and *Whiteinella kingi* (Trujillo). A Coniacian ammonite was collected from NSF 291 in the upper part of the Yolo. (See megafossil data from NSF 291).

NSF 291. See Pessagno (1971a, p. 9).

NSF 316. See Pessagno (1971a, p. 10).

NSF 327-C. Upper part of the Sites Formation at Cache Creek, Yolo County, California. Sample from limestone nodules occurring in gray siliceous mudstones cropping out along Rt. 16. USGS Glascock Mountain Quad. (7.5'); T12N, R4W; Section 2; 0.22 miles due north of Camp Haswell (Boy Scouts of Amer.); about 2675.0 feet above the base of the Sites. Via superposition it can be established that the strata at this locality are Coniacian in age.

NSF 350. Limestone nodule from the lower portion of the "Antelope Shale"/"Fiske Creek Formation" cropping out along the north bank of Cache Creek, Yolo County, California. USGS Glascock Mountain Quad. (7.5'); T12N; R4W; Section 4; 0.13 miles S35°W of Ray-

house Road crossing of Cache Creek at "Low Water Bridge". *NSF 350* occurs 542 feet above a horizon containing common *Praeglobotruncana stephani* (Gandolfi) and 658 feet below beds containing *Rotalipora greenhornensis* (Morrow) and *Rotalipora appenninica* (O. Renz). *NSF 350* likewise occurs 1,047 feet below beds containing *Calycoceras* sp. (late Cenomanian form), *Rotalipora cushmani* (Morrow), *Rotalipora appenninica* (O. Renz), and *Hedbergella brittonensis* Loeblich and Tappan. (Planktonic foraminiferal identifications are the writer's; ammonite identification by D. L. Jones, U.S. Geological Survey, Menlo Park, California.) The planktonic foraminiferal data indicate that *NSF 350* is definitely of Cenomanian age. In that *NSF 350* appears to occur below the *R. cushmani* (Morrow) datum point (cf. Text-Figure 2), it is most likely correlative with the *Rotalipora evoluta* Subzone of Pessagno, 1967, 1969a. Data presented by Renz, Luterbacher, and Schneider (1963, pp. 1073-1116) indicate that *R. cushmani* makes its first appearance within the upper part of the *Mantelliceras mantelli* Zone (early Cenomanian) of the Neuenburger Jura.

NSF 380, 383, 385. "Antelope Shale"/"Fiske Creek Formation". Rhythmically bedded, thin-bedded, medium to dark gray mudstones, siltstones, sandstones, and limestones. *NSF 380*. Limestone nodules in calcareous mudstones. Approximately 504 feet below contact between "Antelope Shale"/"Fiske Creek Formation" and overlying Venado Formation; near small fault.

NSF 385. Limestone nodules in calcareous mudstones; 142 feet below contact between "Antelope Shale"/"Fiske Creek Formation" and the overlying Venado Formation. USGS Glascock Mountain Quadrangle (7.5'); T12N; R4W; Sect. B; exposure on south side of Cache Creek. Abundant specimens of *Inoceramus labiatus* (Schlothheim) (early Turonian) were recovered at *NSF 383* (Identified by D. L. Jones USGS, Menlo Park, California).

NSF 383 is situated 242 feet below the forementioned contact. The same assemblage of Radiolaria occurs at *NSF 383* as at *NSF 380* and *NSF 385*.

NSF 405. See Pessagno (1971a, p. 11).

NSF 432. Venado Formation. Small limestone nodules occurring in dark fissile shales interbedded with massive sandstones. Route 128 near Monticello Dam about 70 feet east of the Solano-Napa

County line. NSF 432 is in close proximity to locality UC B-2040 (cf. Matsumoto, 1960, pp. 37-38) where Turonian ammonites have been recorded (*i.e.*, *Romaniceras* sp. aff. *R. inerme* (de Grossouvier)). Douglas (personal communication and 1968, p. 169) noted "*Praeglobotruncana*" *helvetica* (Bolli) from the lower portion of the Venado Formation at Putah Creek.

NSF 440. Yolo Formation. Limestone nodules interbedded with dark gray shales. Monticello Dam Quad. (7.5'); T8N; R2W; Section 28. North side of Putah Creek (Yolo County); mouth of Thompson Canyon; 0.35 miles due east of north end of Monticello Dam.

NSF 450-NSF 451. Limestone nodules associated with light gray calcareous mudstones. Upper part of Panoche Group (undifferentiated). Exploration Adit number 1: 110-270 feet. California Dept. of Water Resources. Div. of Design and Construction; Del Valle Dam and Reservoir Damsite Foundation Exploration. U.S. Army Corps of Engineers, Tesla Quad. (15'); Co-ordinates E 1,639,000; N 408,250. Associated planktonic Foraminifera at this horizon include *Globotruncana churchi* Martin, *Globotruncana hilli* Pessagno, *Globotruncana linneiana* (d'Orbigny), *Globotruncana arca* (Cushman), *Globotruncana bulloides* Vogler, *Globotruncana rosetta* (Carsey), and *Gublerina ornatissima* (Cushman and Church). Data presented by Pessagno (1967, 1969a) has demonstrated that *Globotruncana hilli* Pessagno first appears at the base of the *Globotruncana calcarata* Zonule. Douglas (1968, p. 154) indicated that *G. churchi* is restricted to the late Campanian.

NSF 482. See Pessagno (1971a, p. 12).

NSF 483. Yolo Formation. Horizon of small limestone nodules in a sequence of dark gray mudstones, siltstones, and sandstones. Monticello Dam Quad. (7.5'); T8N, R2W; Section 28. Route 128 (Solano County) at southeast side of horseshoe bend in road; Cold Canyon; 0.23 miles southwest of Route 128 highway bridge over Putah Creek.

NSF 487. See Pessagno (1971d, p. 293).

NSF 498. See Pessagno (1969b, p. 389).

NSF 518. "Antelope Shale"/"Fiske Creek Formation". Rhythmically bedded, thin-bedded, medium to dark gray mudstones, siltstones, sandstones, and limestones. Sample from limestone nodule: 222 feet below contact with overlying Venado Formation. USGS Wilbur Springs Quadrangle (15'); R4W; T14N: western border of Section 32; roadcut on north side of Rt. 20.

NSF 526. See Pessagno (1971d, p. 293).

NSF 568. See Pessagno (1971d, p. 12).

NSF 591. "Antelope Shale"/"Fiske Creek Formation". Limestone nodule associated with gray siltstones, mudstones, and sandstones; 223 feet below the contact with the overlying Venado Formation. USGS Sites Quadrangle (7.5'). T17N; R4W; Section 4 (S.W. corner); 1.05 miles west of Patterson Road; 2.9 miles N8°W of BM 261 (Section 20) on Sites-Maxwell Road. The radiolarian assemblage at this locality is essentially the same as that occurring in the upper part of the "Antelope Shale"/"Fiske Creek Formation" at Cache Creek. (See megafossil data for *NSF 380, 383, 385.*)

NSF 598. Upper part of the Chickabally Member of the Budden Canyon Formation. Medium gray mudstones interbedded with occasional sandstones; 295 feet below the contact between the Chickabally Member and the Bald Hills Member. USGS Ono Quadrangle (15'); R7W; T28N; Section 4; bluff somewhat north of Rt. 36.

Marianos and Zingula (1966, p. 343; text-fig. 3) included most of the upper portion of the Chickabally Member in the Albian and placed the Albian-Cenomanian boundary somewhat below the contact between the Bald Hills Member and the Chickabally Member (Locality 25 of Marianos and Zingula, *ibid.*). The interval from 50 feet below the Chickabally-Bald Hills contact to several hundred feet below the contact falls within the early Cenomanian. At the horizon of *NSF 598*, Marianos and Zingula recorded a planktonic foraminiferal assemblage with *Planomalina buxtorfi* (Gandolfi), *Praeglobotruncana "delrioensis"* (Plummer) [not *P. delrioensis* (Plummer); = *P. bronnimanni* Pessagno] and *Ticinella roberti* Gandolfi.

NSF 632. See Pessagno (1971d, p. 294).

NSF 647. See Pessagno (1971d, p. 294).

NSF 696. See Pessagno (1971b, p. 362).

NSF 697. See Pessagno (1971a, p. 14).

NSF 705-B. "Marsh Creek Formation". 0.5 miles north of Contra Costa-Alameda County line on Vasco Road (Kellog Creek section). Dark gray siliceous mudstones with limestone nodules. USGS Bryon Hot Spring Quadrangle (7.5') Coniacian.

SYSTEMATIC PALEONTOLOGY

Phylum PROTOZOA

Subphylum SARCODINA

Class ACTINOPODEA

Subclass RADIOLARIA

Order POLYCYSTIDA

Suborder SPUMELLARIINA

Superfamily **SPONGODISCACEA** Haeckel

Remarks. — Pessagno (1971a, p. 16) defined the Spongodiscacea to include Spumellariina with spongy tests of variable shape lacking sieve plates, lattice shells, or chambered rays. The pore frames comprising the spongy meshwork may be arranged with or without symmetry. However, in this report forms having a spongy cortical shell and a latticed medullary shell are included in the Spongodiscacea under the Spungodruppilae Haeckel.

Subsuperfamily **PSEUDOAULOPHACILAE** Riedel

Remarks. — The Pseudoaulophacilae as defined by Pessagno (1971a, p. 19) include only those Spongodiscacea having spongy meshwork arranged symmetrically in spirals, concentric rings, parallel layers, and so forth. The overall shape of the test varies with the family or subfamily.

Family **SPONGURIDAE** Haeckel

Type genus. — *Spongurus* Haeckel.

Emended definition. — Test ellipsoidal, cylindrical or some variation of these shapes with solid spongy meshwork arranged in concentric layers; with or without spines and constrictions.

Remarks. — The Spungodruppinae Haeckel, 1887, are excluded from the Sponguridae in that this group possesses a spongy cortical shell and latticed medullary shell(s). This subfamily should be placed with the Subsuperfamily Spungodruppilae and elevated to family rank.

Range. — Devonian to Recent.

Occurrence. — World-wide.

Subfamily **SPONGURINAE** Haeckel

Type genus. — *Spongurus* Haeckel.

Emended definition. — Spongoridae lacking polar spines, but occasionally having radial spines.

Range. — Devonian to Recent.

Occurrence. — World-wide.

Subfamily **ARCHAEOSPONGOPRUNINAE** Pessagno, n. subfamily

Type genus. — *Archaeospongoprimum*, Pessagno, n. genus.

Definition. — Sponguridae with two massive polar spines.

Remarks. — The Archaeospongoprunitae, n. subfamily, include two genera: *Archaeospongoprimum*, n. gen., and *Spongoprimum* Haeckel. These genera are distinguished from each other by the structure of their polar spines.

Range. — Mesozoic to Recent.

Occurrence. — World-wide.

Genus **ARCHAEOSPONGOPRIMUM** Pessagno, new genus

Type species. — *Archaeospongoprimum venadoensis* Pessagno, n. sp.

Description. — Test cylindrical, ellipsoidal, or ellipsoidal and lobate with two polar spines; polar spines triradiate or tetra-radiate in axial section with longitudinally or spirally arranged ridges alternating with grooves. Spongy meshwork comprised of polygonal pore frames arranged in concentric layers.

Remarks. — *Archaeospongoprimum*, n. gen., differs from *Spongoprimum* Haeckel by possessing polar spines with longitudinal grooves separated by longitudinal ridges. A number of species of *Archaeospongoprimum* have grooves and ridges that assume a spiral rather than a longitudinal arrangement.

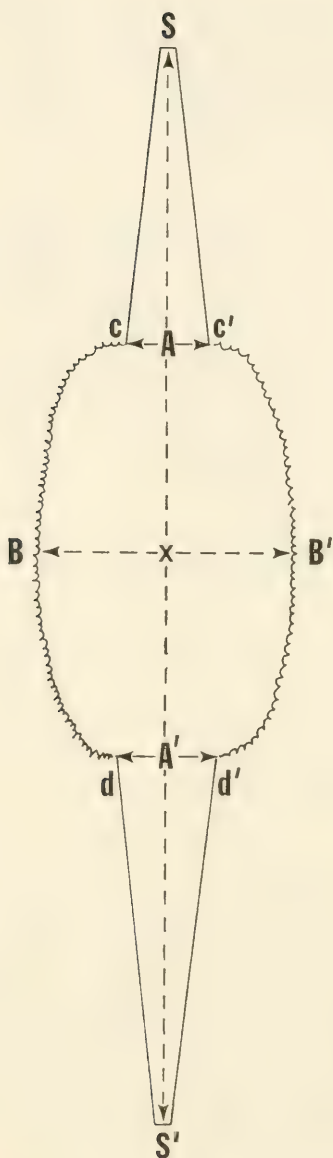
Range. — Jurassic (possibly older) to Cretaceous; ?Eocene. It is likely that *Spongoprimum markleyense* Clark and Campbell (1942) from the Eocene of California should be included under *Archaeospongoprimum*.

Occurrence. — World-wide.

Archaeospongoprimum andersoni Pessagno, n. sp.

Pl. 14, figs. 1-2

Description. — Test elongate, ellipsoidal or subcylindrical in shape with fine meshwork comprised of tetragonal to pentagonal



Text-figure 1.—Form analysis system for measuring spherical or ellipsoidal *Spumellarina* with bipolar spines.

pore frames. Polar spines about equal in length, tetraradiate in axial section with four longitudinally arranged grooves separated by four longitudinally arranged ridges.

Remarks.—*Archaeospongoprunum andersoni*, n. sp., is distinguished from all other species of *Archaeospongoprunum* by its elongate, podlike shape.

This species is named for F. M. Anderson in honor of his studies of the Upper Cretaceous strata of the California Coast Ranges.

Measurements.—See Text-figure 1 for system of form analysis.

Specimen	AA'	A'S	AS	BB'	cc'	dd'
Holotype (USNM 165620)	220 μ	110 μ	—	90 μ	20 μ	20 μ
Paratypes (USNM 165621)	210 μ	—	—	100 μ	25 μ	20 μ
	220 μ	110 μ	—	100 μ	25 μ	20 μ
Paratypes (Pessagno Coll.)	180 μ	120 μ	—	90 μ	20 μ	20 μ
	200 μ	—	—	60 μ	20 μ	—
	190 μ	—	—	90 μ	20 μ	—
	190 μ	—	—	75 μ	20 μ	20 μ

Type locality.—NSF 32-B. Forbes Formation (“Dobbins Shale Member”); early Campanian. See Locality Descriptions.

Deposition of types.—Holotype = USNM 165620. Paratypes = USNM 165621 and Pessagno Collection, University of Texas at Dallas.

Range.—Early Campanian.

Occurrence.—See Text-figure 3 and Locality Descriptions.

Archaeospongoprunum bipartitum Pessagno, n. sp. Pl. 11, figs. 4-6

Description.—Test with two lobes separated by a sulcus. Meshwork coarse and massive on lobes; fine on centrally placed sulcus; pore frames dominantly tetragonal to pentagonal. Polar spines both with three longitudinally arranged grooves alternating with three longitudinally arranged ridges; triradiate in axial section; rare specimens showing slight torsion of ridges and grooves on terminal portions of spines.

Remarks. — *Archaeospongoprimum bipartitum*, n. sp., differs from *Archaeospongoprimum triplum*, n. sp., by having a bilobate test, and considerably coarser meshwork.

bipartitus-a-um (latin) = in two parts.

Measurements. — See Text-figure 1 for system of form analysis.

Specimen	AA'	A'S	AS	BB'	cc'	dd'
Holotype (USNM 165608)	160 μ	140 μ	100 μ	90 μ	30 μ	20 μ
Paratypes (USNM 165609)	180 μ	100 μ	90 ⁺ μ	100 μ	30 μ	20 μ
	160 μ	110 μ	95 ⁺ μ	90 μ	30 μ	20 μ
Paratypes (Pessagno Coll.)	180 μ	—	—	90 μ	30 μ	20 μ
	190 μ	—	120 μ	110 μ	30 μ	20 μ
	170 μ	—	—	90 μ	30 μ	20 μ
	210 μ	130 μ	120 μ	90 μ	30 μ	25 μ
	180 μ	115 μ	90 μ	100 μ	30 μ	25 μ
	160 μ	—	—	90 μ	20 μ	15 μ

Type locality. — NSF 483. Yolo Formation. See Locality Descriptions.

Deposition of types. — Holotype = USNM 165608. Paratypes = USNM 165609 and Pessagno Collection, University of Texas at Dallas.

Range. — Coniacian to Santonian.

Occurrence. — See Text-figure 3 and Locality Descriptions.

Archaeospongoprimum cortinaensis Pessagno, n. sp. Pl. 9, figs. 4-6

Description. — Test slender, ellipsoidal with meshwork comprised of dominantly pentagonal pore frames. One polar spine somewhat shorter than other; tetra-rotate with loose, clockwise arrangement of grooves and ridges. Opposite spine tetra-rotate with longitudinally arranged grooves and ridges; grooves about twice as wide as ridges.

Remarks. — *A. cortinaensis*, n. sp., differs from *A. venadoensis*, n. sp., by having a much slenderer test and distinctly different polar spines.

- a. Last appearance Globotruncana linneiana (d'Orbigny)
- b. First appearance Globotruncana hilli Pessagno
- c. First appearance Globotruncana arca (Cushman)
- d. First appearance double-keeled Globigerinacea
- e. First appearance Rotalipora evoluta Sigal

[illegible]

A. cortinaensis, n. sp., derives its name from Cortina Ridge in Colusa County, California.

Measurements. — See Text-figure 1 for system of form analysis.

Specimen	AA'	A'S	AS	BB'	cc'	dd'
Holotype (USNM 165602)	110 μ	90 μ	90 μ	80 μ	30 μ	20 μ
Paratypes (USNM 165603)	125 μ	103 μ	100 μ	75 μ	20 μ	20 μ
	110 μ	110 μ	95 μ	70 μ	20 μ	15 μ
	110 μ	—	100 μ	80 μ	20 μ	20 μ
	120 μ	—	85 μ	65 μ	25 μ	20 μ
Paratypes (Pessagno Coll.)	110 μ	—	115 μ	90 μ	25 μ	25 μ
	120 μ	—	100 μ	80 μ	20 μ	20 μ
	110 μ	110 μ	100 μ	70 μ	20 μ	20 μ
	110 μ	100 μ	105 μ	70 μ	25 μ	20 μ
	120 μ	105 μ	105 μ	90 μ	20 μ	25 μ

Type locality. — NSF 350. "Antelope Shale"/"Fiske Creek Formation". See Locality Descriptions.

Deposition of types. — Holotype = USNM 165602. Paratypes = USNM 165603 and Pessagno Collection, University of Texas at Dallas.

Range. — Early Cenomanian to early Coniacian.

Occurrence. — See Text-figure 3 and Locality Descriptions.

***Archaeospongoprimum hueyi* Pessagno, n. sp.**

Pl. 13, fig. 1

Description. — Test elongate, ellipsoidal with fine spongy meshwork consisting of triangular, tetragonal (usually square), and pentagonal pore frames. Polar spines tetraradiate in axial section with four longitudinally arranged grooves interspersed between four longitudinally arranged ridges.

Remarks. — *Archaeospongoprimum hueyi*, n. sp., is most closely related to *Archaeospongoprimum stocktonensis*, n. sp. Like the latter species it possesses polar spines which are tetraradiate in axial section and meshwork comprised of triangular, tetragonal, and pentagonal pore frames. *A. hueyi*, n. sp., differs from *A. stocktonensis*, n. sp., by having longitudinally rather than spirally arranged grooves and ridges.

This species is named for Arthur Huey who mapped the Tesla Quadrangle.

Measurements. — See Text-figure 1 for system of form analysis.

Specimen	AA'	A'S	AS	BB'	cc'	dd'
Holotype (USNM 165628)	150 μ	—	—	80 μ	20 μ	20 μ
Paratypes (USNM 165629)	110 μ	90 μ	90 μ	60 μ	20 μ	20 μ
	140 μ	—	110 μ	70 μ	20 μ	15 μ
Paratypes (Pessagno Coll.)	130 μ	—	147 μ	80 μ	25 μ	20 μ
	80 μ	—	—	65 μ	20 μ	20 μ
	120 μ	—	112 μ	60 μ	25 μ	20 μ
	100 μ	—	—	70 μ	20 μ	20 μ

Type locality. — NSF 451; late Campanian portion of the Panoche Group. See Locality Descriptions.

Deposition of types. — Holotype = USNM 165628. Paratypes = USNM 165629 and Pessagno Collection, University of Texas at Dallas.

Range. — Late Campanian.

Occurrence. — See Text-figure 3 and Locality Descriptions.

Archaeospongoprimum rumseyensis Pessagno, n. sp. Pl. 12, figs. 3-6

Description. — Test an oblate ellipsoid; about half as wide as long. Meshwork quite fine with a preponderance of tetragonal pore frames. One polar spine with grooves and ridges arranged in a clockwise spire. Other polar spine triradiate in axial section with three longitudinally arranged grooves alternating with three longitudinally arranged ridges.

Remarks. — *Archaeospongoprimum rumseyensis*, n. sp., differs from *Archaeospongoprimum vascoensis*, n. sp., by possessing a proportionately wider test, finer meshwork with a preponderance of tetragonal frames, and one polar spine which shows a well-developed spiral arrangement of grooves and ridges. This species is named after the town of Rumsey, Yolo County, California.

Measurements. — See Text-figure 1 for system of form analysis.

Specimen	AA'	A'S	AS	BB'	cc'	dd'
Holotype (USNM 165612)	170 μ	—	—	110 μ	20 μ	20 μ
Paratypes (USNM 165613)	155 μ	—	—	110 μ	20 μ	20 μ
	185 μ	—	—	120 μ	30 μ	25 μ
	190 μ	—	—	170 μ	30 μ	20 μ
	190 μ	—	—	140 μ	—	—
	160 μ	—	85 μ	110 μ	20 μ	20 μ
Paratypes (Pessagno Coll.)	165 μ	—	90 μ	115 μ	—	20 μ
	180 μ	—	—	130 μ	—	—

Type locality. — NSF 327-C. Sites Formation. See Locality Descriptions.

Deposition of types. — Holotype = USNM 165612. Paratypes = USNM 165613 and Pessagno Collection, University of Texas at Dallas.

Range. — Coniacian.

Occurrence. — See Text-figure 3 and Locality Descriptions.

***Archaeospongoprunum salumi* Pessagno, n. sp.**

Pl. 13, figs. 2-5

Description. — Test ellipsoidal with fine meshwork comprised of triangular to tetragonal (square) pore frames. Polar spines about equal in length; one spine tetraradiate in axial section with four grooves alternating with four ridges; ridges and grooves arranged in a loose clockwise spiral. Other polar spine triradiate in axial section with three longitudinally placed grooves and three longitudinally placed ridges.

Remarks. — *Archaeospongoprunum salumi*, n. sp., can be easily confused with *Archaeospongoprunum cortinaensis*, n. sp. It differs from the latter species by having meshwork consisting of triangular to tetragonal pore frames and by having one polar spine which is triradiate and another which is tetraradiate in axial section.

salumus, -i (Latin, M) = the open sea.

Measurements. — See Text-figure 1 for system of form analysis.

Specimen	AA'	A'S	AS	BB'	cc'	dd'
Holotype (USNM 165622)	120 μ	130 μ	120 μ	90 μ	20 μ	20 μ
Paratypes (USNM 165623)	100 μ	—	105 μ	80 μ	25 μ	18 μ
	125 μ	110 μ	120 μ	80 μ	20 μ	20 μ
	125 μ	100 μ	100 μ	90 μ	20 μ	15 μ
	120 μ	—	—	80 μ	20 μ	20 μ
Paratype (Pessagno Coll.)	140 μ	160 μ	140 μ	100 μ	25 μ	25 μ
	120 μ	140 μ	110 μ	80 μ	20 μ	20 μ
	140 μ	130 μ	115 μ	80 μ	30 μ	25 μ
	110 μ	—	80 μ	80 μ	20 μ	20 μ
	130 μ	—	95 μ	90 μ	20 μ	20 μ

Type locality. — NSF 32-B. Forbes Formation ("Dobbins Shale Member"); early Campanian.

Deposition of types. — Holotype = USNM 165622. Paratypes = USNM 165623 and Pessagno Collection, University of Texas at Dallas.

Range. — Early Campanian.

Occurrence. — See Text-figure 3 and Locality Descriptions.

Archaeospongoprimum stocktonensis Pessagno, n. sp. Pl. 13, fig. 6.

Description. — Test ellipsoidal, often subspherical with fine meshwork consisting of triangular, tetragonal, and pentagonal pore frames. Polar spines tetra-rotate in axial section with four grooves and four ridges arranged in a loose clockwise spire on one spine and a loose counterclockwise spire on the other spine.

Remarks. — *Archaeospongoprimum stocktonensis*, n. sp., superficially resembles *Archaeospongoprimum venadoensis*, n. sp. It can be distinguished from the latter form by the structure of its meshwork and loose spiral arrangement of ridges and grooves on its polar spines.

This species is named for Stockton, California.

Measurements. — See Text-figure 1 for system of form analysis.

Specimen	AA'	A'S	AS	BB'	cc'	dd'
Holotype (USNM 165624)	120 μ	140 μ	148 μ	80 μ	30 μ	20 μ
Paratypes (USNM 165625)	110 μ	130 μ	130 μ	95 μ	30 μ	20 μ
	110 μ	110 μ	125 μ	85 μ	30 μ	20 μ
	120 μ	110 μ	120 μ	85 μ	25 μ	20 μ
	110 μ	—	—	90 μ	30 μ	20 μ
Paratypes (Pessagno Coll.)	120 μ	—	100 μ	90 μ	25 μ	20 μ
	90 μ	—	—	80 μ	20 μ	20 μ
	120 μ	—	100 μ	80 μ	30 μ	20 μ
	120 μ	—	—	100 μ	30 μ	20 μ
	100 μ	110 μ	115 μ	90 μ	20 μ	20 μ
	110 μ	135 μ	—	85 μ	25 μ	20 μ
	90 μ	—	110 μ	60 μ	20 μ	20 μ

Type locality.—NSF 451: late Campanian portion of the Panoche Group. See Locality Descriptions.

Deposition of types.—Holotype = USNM 165624. Paratypes = USNM 165625 and Pessagno Collection, University of Texas at Dallas.

Range.—Late Campanian.

Occurrence.—See Text-figure 3 and Locality Descriptions.

Archaeospongoprimum tehamaensis Pessagno, n. sp. Pl. 9, figs. 2-3

Description.—Test exclusive of polar spines small, ellipsoidal with irregularly shaped tetragonal and pentagonal pore frames. Polar spines long, massive, tetraradiate in axial section with four longitudinally arranged ridges alternating with four longitudinally arranged grooves. Grooves on polar spines about twice as wide as ridges.

Remarks.—*Archaeospongoprimum tehamaensis*, n. sp., differs from *Archaeospongoprimum cortinaensis*, n. sp., by having much longer, more massive polar spines which lack a spiral arrangement of grooves and ridges. It is possible that *A. tehamaensis* represents the ancestral form of *A. cortinaensis*. Both species share tetraradiate polar spines and similarly shaped tests.

This species is named for Tehama County, California.

Measurements. — See Text-figure 1 for system of form analysis.

Specimen	AA'	A'S	AS	BB'	cc'	dd'
Holotype (USNM 165614)	75 μ	—	—	70 μ	20 μ	20 μ
Paratype (USNM 165615)	135 μ	—	—	102 μ	20 μ	20 μ
Paratypes (Pessagno Coll.)	100 μ	—	—	60 μ	20 μ	—
	100 μ	—	—	70 μ	20 μ	20 μ
	180 μ	—	—	100 μ	20 μ	—
	110 μ	—	—	80 μ	20 μ	—
	100 μ	—	—	80 μ	25 μ	—

Type locality. — NSF 598-C. Budden Canyon Formation (Chickabally Member). See Locality Descriptions.

Deposition of types. — Holotype = USNM 165614. Paratypes = USNM 165615 and Pessagno Collection, University of Texas at Dallas.

Range and occurrence. — Thus far, this species has only been found at its type locality in strata of earliest Cenomanian.

Archaeospongoprimum triplum Pessagno, n. sp.

Pl. 10, figs. 5-6
Pl. 11, figs. 1-3

Description. — Test elongate, cylindrical with three distinct lobes and meshwork comprised of pentagonal pore frames. Central lobe with finer meshwork than that of the lateral lobes; lobes separated by two sulci. One polar spine triradiate with three prominent longitudinal grooves separating three prominent longitudinal ridges; rarely showing slight torsion of ridges and grooves. Opposite spine shorter with spiral clockwise arrangement of ridges and grooves.

Remarks. — *Archaeospongoprimum triplum*, n. sp., differs from *Archaeospongoprimum cortinaensis*, n. sp., by having a test which is considerably more elongate and which is subdivided into three distinct lobes. Both species share similar polar spines. It is likely that *A. triplum* evolved from *A. cortinaensis* through lengthening and the subdivision of the latter forms test into three lobes. Inter-

mediate form with a somewhat shorter length and indistinct lobes occur in some samples.

tripplus-a-um (Latin, adj.) = threefold, triple.

Measurements. — See Text-figure 1 for system of form analysis.

Specimen	AA'	A'S	AS	BB'	cc'	dd'
Holotype (USNM 165606)	200 μ	140 μ	110 μ	60 μ	20 μ	20 μ
Paratypes (USNM 165607)	180 μ	130 μ	100 μ	75 μ	30 μ	30 μ
	175 μ	120 μ	95 μ	65 μ	25 μ	20 μ
	175 μ	—	105 μ	70 μ	25 μ	25 μ
	165 μ	105 μ	90 μ	60 μ	20 μ	20 μ
Paratypes (Pessagno Coll.)	190 μ	—	—	70 μ	30 μ	20 μ
	180 μ	120 μ	—	70 μ	20 μ	20 μ
	210 μ	—	—	80 μ	20 μ	20 μ
	200 μ	125 μ	115 μ	90 μ	30 μ	20 μ
	180 μ	120 μ	—	70 μ	30 μ	30 μ

Type locality. — NSF 483. Yolo Formation. See Locality Descriptions.

Deposition of types. — Holotype = USNM 165606. Paratypes = USNM 165607 and Pessagno Collection, University of Texas at Dallas.

Range. — Early Coniacian.

Occurrence. — See Text-figure 3 and Locality Descriptions.

Archaeospongoprunum vascoensis Pessagno, n. sp.

Pl. 10, fig. 1

Description. — Test subcylindrical. Meshwork with dominance of tetragonal pore frames. One polar spine tetraradiate in axial section; having four longitudinally arranged narrow, grooves and four longitudinally arranged wider ridges. Other polar spine tetraradiate with similar grooves and ridges arranged in a slight clockwise spiral.

Remarks. — *A. vascoensis*, n. sp., differs from *A. cortinaensis*, n. sp., by having a subcylindrically shaped test. Like *A. cortinaensis*, *A. vascoensis* possesses polar spines which are tetraradiate in axial section. Though both species display one polar spine with a clockwise spiralling of ridges and grooves, spiralling with *A. vascoensis* is less pronounced.

This species is named for Vasco Road in its type area.

Measurements. — See Text-figure 1 for system of form analysis.

Specimen	AA'	A'S	AS	BB'	cc'	dd'
Holotype (USNM 165610)	200 μ	155 μ	150 μ	150 μ	30 μ	30 μ
Paratypes (USNM 165611)	210 μ	—	140 μ	140 μ	30 μ	30 μ
	190 μ	160 μ	155 μ	140 μ	40 μ	30 μ
Paratypes (Pessagno Coll.)	180 μ	—	110 μ	120 μ	30 μ	—
	180 μ	—	100 μ	120 μ	35 μ	30 μ
	170 μ	—	140 μ	125 μ	40 μ	30 μ
	200 μ	—	—	150 μ	40 μ	30 μ

Type locality. — NSF 705. "Marsh Creek Formation". See Locality Descriptions.

Deposition of types. — Holotype = USNM 165610. Paratypes = USNM 165611 and Pessagno Collection, University of Texas at Dallas.

Range. — Middle Turonian to early Coniacian.

Occurrence. — See Text-figure 3 and Locality Descriptions.

Archaeospongoprimum venadoensis Pessagno, n. sp. Pl. 10, figs. 2-3

Description. — Test broadly ellipsoidal with meshwork consisting for the most part of tetragonal pore frames. Polar spines equal in length, tetra- or hexaradiate in axial section with four spirally arranged grooves alternating with four spirally arranged ridges; one spine with clockwise spiral arrangement of ridges and grooves and the other with a counter clockwise spiral arrangement of ridges and grooves.

Remarks. — *A. venadoensis*, n. sp., has been compared with *A. cortinaensis*, n. sp., under the latter species. *A. venadoensis* differs from all other species of *Archaeospongoprimum* by having polar spines with grooves and ridges arranged in a tight spire.

It is likely that *A. venadoensis* arose from *A. cortinaensis* via acquiring a second polar spine with spirally arranged grooves and a more inflated test.

This species is named for the ghost town of Venado (= "Mountain House") in Colusa County, California.

Measurements. — See Text-figure 1 for system of form analysis.

Specimen	AA'	A'S	AS	BB'	cc'	dd'
Holotype (USNM 165604)	150 μ	90 μ	80 μ	110 μ	20 μ	15 μ
Paratypes (USNM 165605)	160 μ	65 μ	70 μ	110 μ	20 μ	20 μ
	160 μ	95 μ	95 μ	120 μ	20 μ	20 μ
	120 μ	70 μ	—	90 μ	20 μ	15 μ
Paratypes (Pessagno Coll.)	130 μ	90 μ	—	100 μ	—	15 μ
	120 μ	—	—	110 μ	—	15 μ
	170 μ	—	90 μ	130 μ	20 μ	—
	150 μ	80 μ	80 μ	100 μ	20 μ	20 μ
	150 μ	—	—	110 μ	20 μ	—

Type locality. — NSF 432. Venado Formation. See Locality Descriptions.

Deposition of types. — Holotype = USNM 165604. Paratypes = USNM 165605 and Pessagno Collection, University of Texas at Dallas.

Range. — Middle Turonian to late Turonian.*

Occurrence. — See Text-figure 3 and Locality Descriptions.

Archaeospongoprimum sp. aff. **A. venadoensis** Pessagno, n. sp.

Pl. 10, fig. 4

Remarks. — This form differs from *A. venadoensis*, n. sp., by having a much more spherical test and a mixture of both tetragonal and pentagonal pore frames. Both *A. venadoensis* and *A. sp. aff. A. venadoensis* possess spines with spirally arranged grooves and ridges.

Range. — Early to late Cenomanian.

Occurrence. — NSF 350 and NSF 405. "Antelope Shale"/"Fiske Creek Formation". See Locality Descriptions. Only several specimens of this form have been found in the writer's material.

Archaeospongoprimum sp. A.

Pl. 12, fig. 2

Remarks. — This form is characterized by having a cylindrical test. One polar spine is triradiate(?) with longitudinally arranged grooves and ridges. The other shows a clockwise spiral arrangement of grooves and ridges.

*Range shown in Text-figure 2 is incorrect.

Only two specimens of *Archaeospongoprunum* sp. A. occur in the writer's material. Both of these specimens come from separate localities.

Range. — Coniacian in so far as known.

Occurrence. — Yolo Formation, NSF 291-C and NSF 483-B.

***Archaeospongoprunum* sp. B.**

Pl. 12, fig. 1

Remarks. — *A.* sp. B. is characterized by having an ellipsoidal test which is somewhat flattened along its long axis. One polar spine is about one-third the length of the other polar spine and possesses six short, longitudinal ridges alternating with six short longitudinal grooves. The large spine possesses three spirally arranged grooves alternating with three spirally arranged ridges; the spiralling tends to be clockwise.

Range and occurrence. — This form is rare in the Great Valley Sequence. One specimen was encountered in the lower part of the Venado Formation (NSF 697) and another in the upper part of the Yolo Formation (NSF 291-C). See Locality Descriptions.

***Archaeospongoprunum* sp. C.**

Pl. 14, fig. 3

Remarks. — This form possesses an elongate, ellipsoidal test somewhat similar to that of *A. andersoni*, n. sp. It differs from the latter species by having tetraradiate polar spines, one of which shows a clockwise spiral arrangement of ridges and grooves and the other of which shows a counter clockwise spiral arrangement of ridges and grooves.

Range and occurrence. — Early Campanian portion of the Forbes Formation ("Dobbins Shale Member") at NSF 32-B.

***Archaeospongoprunum* sp. D.**

Pl. 14, fig. 4

Remarks. — This form is characterized by its short subcylindrical test with tetragonal (square) pore frames. The nodes at the vertices of the polygonal pore frames appear to be unusually massive. One polar spine is short, tetraradiate and somewhat greater in diameter with a clockwise arrangement of grooves and ridges. The other polar spine appears to be longer and triradiate in axial section with a longitudinal arrangement of ridges and grooves.

Range and occurrence. — Early Campanian portion of the Forbes Formation ("Dobbins Shale Member") in so far as known.

Archaeospongoprunum sp. E.

Pl. 14, fig. 5

Remarks.—*Archaeospongoprunum* sp. E. is characterized by its inflated ellipsoidal test with one short, peculiarly shaped polar spine which is tetra-radiate in axial section and one longer polar spine which is tri-radiate in axial section. The shorter spine is unique in that its ridges are wider medianly than they are proximally.

Range and occurrence.—Early Campanian portion of the Forbes Formation ("Dobbins Shale Member"). NSF 32-B. See Locality Descriptions.

Family **ORBICULIFORMIDAE** Pessagno, n. family

Type genus.—*Orbiculiforma* Pessagno, n. genus.

Description.—Test disc-shaped with irregular polygonal pore frames arranged in concentric rings. With or without equatorially placed spines.

Remarks.—According to the Haeckelian classification utilized in the Treatise on Invertebrate Paleontology (Campbell and Moore, 1954) this group of Spongodiscacea would have been placed in the Spongodiscidae Haeckel. The writer prefers, however, to restrict the Spongodiscidae to forms displaying spongy, disc-shaped tests lacking pore frames arranged in a symmetrical fashion.

A number of genera included by Campbell (1954, pp. D93-D94) under the Spongodiscidae will probably have to be reassigned to the Orbiculiformidae, n. family.

Range and occurrence.—The stratigraphic distribution of the Orbiculiformidae is still not fully documented. This family is certainly well represented in the Cretaceous of both the Boreal and Tethyan faunal provinces.

Genus **ORBICULIFORMA** Pessagno, n. genus

Type species.—*Orbiculiforma quadrata* Pessagno, n. sp.

Description.—Test circular to square in outline with short peripheral spines. Center of test markedly depressed; central cavity flanked by prominent rim. Central cavity occasionally obscured by fragile secondary meshwork (Pl. 17, fig. 5).

Remarks.—*Orbiculiforma*, n. gen., differs from *Stylospongia* Haeckel by having a disc-shaped test with concentric meshwork throughout and central cavities on opposing sides of the test.

Orbiculus, i(m.) = a little circle or disc + *forma*, -ae (Latin, f.) = shape, form.

Range. — Upper Cretaceous.

Occurrence. — Great Valley Sequence, California Coast Ranges.

Orbiculiforma monticelloensis Pessagno, n. sp.

Pl. 16, figs. 5-6;

Pl. 18, figs. 1-2

Description. — Test as with genus; nearly circular in outline with rounded periphery and an undetermined number of small, triradiate peripheral spines. Meshwork both laterally and peripherally consisting predominantly of tetragonal and pentagonal pore frames with a few rare triangular pore frames. Central cavity relatively wide and shallow with finer meshwork; center of central cavity slightly raised.

Remarks. — *O. monticelloensis*, n. sp., is compared with *O. quadratus*, n. sp., under the latter species. It differs from *O. vacaensis*, n. sp., by having a rounded periphery, no peripheral indentations, a thinner test, and a shallow central cavity.

This species is named for Monticello Dam near its type locality.

Measurements. —

Specimen	Maximum Width	Maximum Length of Spines	Maximum Width of Central Cavity
Holotype (USNM 165632)	290 μ	—	150 μ
Paratype (USNM 165633)	240 μ	10 μ	130 μ
	240 μ	20 μ	140 μ
	330 μ	20 μ	170 μ
	245 μ	10 μ	130 μ
	250 μ	10 μ	130 μ
Paratypes (Pessagno Coll.)	270 μ	—	150 μ
	280 μ	—	120 μ
	285 μ	20 μ	150 μ
	300 μ	—	170 μ

Type locality.—NSF 483. Yolo Formation. See Locality Descriptions.

Deposition of types.—Holotype = USNM 165632. Paratypes = USNM 165633 and Pessagno Collection, University of Texas at Dallas.

Range.—Turonian to Santonian.

Occurrence.—See Text-figure 3 and Locality Descriptions.

Orbiculiforma quadrata Pessagno, n. sp. Pl. 16, figs. 1-4; Pl. 18, fig. 3

Description.—Test as with genus, nearly square in outline with four triradiate spines, each situated at vertex. Periphery rounded with meshwork comprised of massive square and triangular pore frames; remainder of test with mixture of triangular, tetragonal, and pentagonal pore frames. Central cavity deep with somewhat finer meshwork which tends to be denser along two axes in line with spines forming a spongy cross; center of central cavity slightly raised.

Remarks.—*O. quadrata*, n. sp., differs from *O. monticelloensis*, n. sp., by having a square test, four spines, and a spongy cross in its central cavity. *O. quadrata*, n. sp., is compared to *O. vacaensis*, n. sp., under the latter species.

quadratus-a-um (Latin, adj.) = square.

Measurements.—

Specimen	Maximum Width	Maximum Length of Spines	Maximum Width of Central Cavity
Holotype (USNM 165630)	240 μ	25 μ	180 μ
Paratypes (USNM 165631)	240 μ	—	170 μ
	220 μ	35 μ	140 μ
	250 μ	40 μ	160 μ
	230 μ	—	160 μ
	260 μ	—	170 μ
Paratypes (Pessagno Coll.)	230 μ	30 μ	150 μ
	250 μ	30 μ	150 μ
	230 μ	—	130 μ
	280 μ	—	200 μ

Type locality. — NSF 483. Yolo Formation. See Locality Descriptions.

Deposition of types. — Holotype = USNM 165630. Paratypes = USNM 165631 and Pessagno Collection, University of Texas at Dallas.

Range. — Coniacian to Santonian.

Occurrence. — See Text-figure 3 and Locality Descriptions.

Orbiculiforma vacaensis Pessagno, n. sp.

Pl. 17, figs. 1-6

Description. — Test as with genus; nearly circular in outline with a vertical periphery; test thick with a shallow U-shaped indentation along one side; indeterminate number of short peripheral spines which are tetragonal in axial section and bear small subsidiary spines. Central cavity wide and deep; center slightly raised. Meshwork consisting of a mixture of triangular, tetragonal (often square), and pentagonal pore frames.

Remarks. — This species is characterized by its steep-sided, vertical periphery, thick test, and U-shaped peripheral indentation. It differs from *O. quadrata*, n. sp., by having a circular test, more numerous peripheral spines, and by the characteristics cited above. *O. vacaensis*, n. sp., is compared with *O. monticelloensis*, n. sp., under the latter species.

This species is named for Mt. Vaca, Solano-Napa Counties, California.

Measurements. —

Specimen	Maximum Width	Maximum Length of Spines	Maximum Width of Central Cavity
Holotype (USNM 165634)	285 μ	—	220 μ
Paratypes (USNM 165635)	320 μ	—	240 μ
	320 μ	—	220 μ
	300 μ	—	200 μ

Paratypes

(Pessagno Coll.)	300 μ	—	200 μ
	280 μ	—	220 μ
	310 μ	—	230 μ
	320 μ	—	230 μ
	340 μ	20 μ	250 μ
	370 μ	—	270 μ

Type Locality. — NSF 440. Yolo Formation. See Locality Descriptions.

Deposition of types. — Holotype = USNM 165634. Paratypes = USNM 165635 and Pessagno Collection, University of Texas at Dallas.

Range. — Coniacian.

Occurrence. — See Text-figure 3 and Locality Descriptions.

Subsuperfamily **SPONGODRUPPILAE HAECKEL**

Definition. — Spongodiscacea with a spongy cortical shell and one or more latticed medullary shells (Pl. 15, figs. 4-6). Cortical shell varying in shape with family or subfamily. Spongy cortical shell comprised of concentric layers of polygonal pore frames. Latticed medullary shell(s) connected to cortical shell by variable number of radial beams.

Remarks. — Recently, Pessagno (1971a) divided the Spongodiscacea into two subsuperfamilies, the Spongodiscilae Haeckel and the Pseudoaulophacilae Riedel. The Spongodruppilae Haeckel differ from both the Spongodiscilae and the Pseudoaulophacilae by possessing a spongy cortical shell and a latticed medullary shell or shells. The Spongodruppiniae Haeckel should be elevated to family rank and placed in this superfamily.

Range. — ?Paleozoic; Mesozoic; Cenozoic.

Occurrence. — World-wide.

Family **CAVASPONGIDAE**, n. family

Type genus. — *Cavaspongia*, n. genus.

Description. — Spongodruppilae of variable shape having a spongy cortical shell comprised of polygonal pore frames arranged in an indeterminate number of concentric layers. Cortical shell

connected by radial beams (either solid or spongy or both) to a latticed medullary shell.

Remarks.—The *Cavaspongidae* differ from the “*Spongolarcida*” Haeckel by possessing a hollow, spongy cortical shell and a latticed medullary shell. Although Haeckel (1887, p. 613) stated that the “*Spongolarcida*” occur both with or without medullary shells, he also stated that the only two genera that he included in this group (*i.e.*, *Spongolarcus* Haeckel and *Stypolarcus* Haeckel) lack medullary shells.

Range and occurrence.—Upper Cretaceous of the Great Valley Sequence, California Coast Ranges in so far as known.

Genus **CAVASPONGIA** Pessagno, new genus

Type species.—*Cavaspongia antelopensis* Pessagno, n. sp.

Description.—Test biconvex with a three-rayed cortical shell having three lateral gates situated in area between rays. Rays equal in length, inclined in a distal direction from central area to ray tips. Ray tips with variable number of short, solid lateral spines situated to either side of a large, massive, spongy central spine which is broken on all specimens thus far examined. Cortical shell connected to latticed medullary shell by three massive, spongy, hollow beams which are continuous with central spines of ray tips; indeterminate number of thin, radially arranged solid spines connecting medullary shell to roof of cortical shell.

Remarks.—*Cavaspongia*, n. genus, is compared with *Pyramispongia*, n. genus, under the latter genus. It differs from *Paronaella* Pessagno by possessing three prominent laterally placed gates and by having a hollow cortical shell connected to a latticed medullary shell by various sorts of spines.

cavus-a-um (Latin, adj.) = hollow + *spongia*, -ae (Latin, f.) = sponge.

Range.—Upper Cretaceous in so far as known.

Occurrence.—Great Valley Sequence, California Coast Ranges.

Cavaspongia antelopensis Pessagno, n. sp. Pl. 18, figs. 4-6; Pl. 19, fig. 1

Description.—Test as with genus. Rays considerably wider proximally than distally rapidly tapering toward their rounded tips. Spongy tubular central spines and solid lateral spines circular in axial section. Meshwork fine, predominantly tetragonal to penta-

gonal; occasionally triangular. Meshwork of tubular central spines tetragonal (usually square).

Remarks.—*Cavaspongia antelopensis*, n. sp., differs from *Cavaspongia californiensis*, n. sp., by having rapidly tapering rays and a more poorly defined central area.

This species is named for Antelope Valley near Sites, Colusa County, California.

Measurements.—Length of rays measured from center of central area to ray tip exclusive of spines:

Holotype USNM 165636: 150 microns.

Average for holotype and ten paratypes: 170 microns.

Type locality.—NSF 591. "Antelope Shale"/"Fiske Creek Formation". See Locality Descriptions.

Deposition of types.—Holotype = USNM 165636. Paratypes = USNM 165637 and Pessagno Collection, University of Texas at Dallas.

Range.—Early Turonian.

Occurrence.—See Text-figure 3 and Locality Descriptions.

***Cavaspongia californiensis* Pessagno, n. sp.**

Pl. 19, figs. 2-4

Description.—Test as with genus. Rays wider distally than proximally; ray tips with hollow, massive, spongy central spines flanked by indeterminate number of small, solid somewhat irregularly shaped lateral spines. Meshwork with predominantly tetragonal to pentagonal pore frames. Pore frames of central spines tetragonal (usually square).

Remarks.—*Cavaspongia californiensis*, n. sp., has been compared to *C. antelopensis* under the latter species.

Measurements.—Length of rays measured from center of central area to ray tip exclusive of spines:

Holotype USNM 165638: 180 microns.

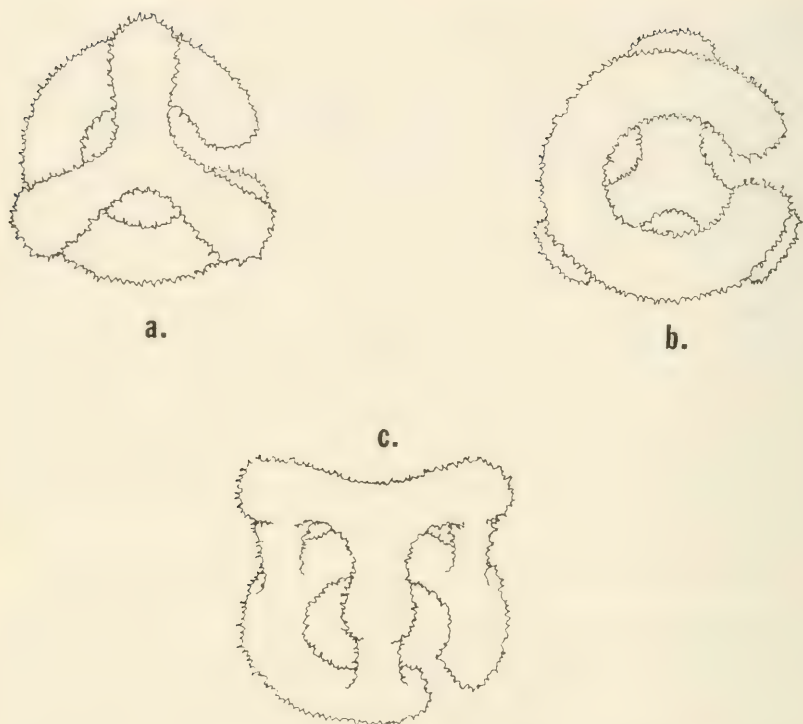
Average for holotype and nine paratypes: 181 microns.

Type locality.—NSF 591. "Antelope Shale"/"Fiske Creek Formation." See Locality Descriptions.

Deposition of types.—Holotype = USNM 165638. Paratypes = USNM 165639 and Pessagno Collection, University of Texas at Dallas.

Range.—Early Turonian.

Occurrence.—See Text-figure 3 and Locality Descriptions.



Text-figure 4. — Cortical frame of *Pyramispongia magnifica* Pessagno, n. sp. (See Plates 20 and 21).

Genus **PYRAMISPONGIA** Pessagno, n. genus

Type species. — *Pyramispongia magnifica*, Pessagno, n. sp.

Description. — Cortical shell spongy, subpyramidal in shape with cupolae situated at four corners of shell (Pl. 19, figs. 5-6; Pl. 13, figs. 2, 4); cupola arising from shelflike ring. Cortical shell often spinose with massive spines arising from center of cupolae. Cortical shell molded around peculiar spongy cortical frame (Pl. 20, figs. 2-6; Pl. 21, fig. 1; Text-fig. 4). Latticed medullary shell spherical in shape connected to cortical shell by radially arranged solid beams which appear to be continuous with solid spines of cortical shell.

Remarks. — *Pyramispongia*, n. genus, differs from *Cavaspongia*, n. genus, by possessing a subpyramidal cortical shell with four cupolas, by possessing solid rather than spongy radial beams, and by possessing a cortical frame. The cortical frame of *Pyramispongia*,

n. genus, was first interpreted as a separate genus of Cavaspongidae. Cortical frames of *Pyramispongia magnifica*, n. sp., are common in the early Turonian sediments of the Great Valley Sequence — often at widely separated localities. Eventually, it was established after examining broken specimens of *P. magnifica* that this structure was merely a part of the cortical shell. Assumedly, the cortical frame served as a strengthening mechanism for the cortical shell.

Pyramis (Latin, f.) = a pyramid + *spongia* (Latin, f.) = sponge.

Range. — Upper Cretaceous; early Cenomanian to early Turonian in so far as known.

Occurrence. — Great Valley Sequence, California Coast Ranges.

***Pyramispongia glascocksensis*, n. sp.**

Pl. 21, figs. 2-5

Description. — Test as with genus; meshwork of cortical shell comprised dominantly of pentagonal and hexagonal pore frames; occasionally with tetragonal pore frames. Cupolae rounded, large; each with centrally placed spine displaying a weak closewise spiral arrangement of three ridges alternating with three grooves. Narrow shelf surrounding cupolae with massive, raised, tetragonal pore frames. Structure of medullary shell not known at present.

Remarks. — *Pyramispongia glascocksensis*, n. sp., differs from *P. magnifica*, n. sp., by having larger, more inflated cupolae; by having narrower shelves surrounding the cupolae, and by having centrally placed spines on the cupolae which display a weak spiral arrangement of ridges and grooves; by being considerably less spinose; and so forth.

This species is named for Glascock Mountain, Yolo County, California.

Measurements. —

Specimen	Maximum Width of Test (exclusive of spines)	Maximum Length of spines
Holotype (USNM 165642)	240 μ	70 μ
	Average for holotype and nine paratypes = 210 μ	Average for holotype and three paratypes = 63.7 μ

Type locality.—NSF 350. “Antelope Shale”/“Fiske Creek Formation”. See Locality Descriptions.

Deposition of types.—Holotype = USNM 165642. Paratypes = USNM 165643 and Pessagno Collection, University of Texas at Dallas.

Range.—Cenomanian.

Occurrence.—See Text-figure 3 and Locality Descriptions.

Pyramispongia magnifica Pessagno, n. sp.

Pl. 19, figs. 5-6;

Pl. 20, figs. 1-6; Pl. 21, fig. 1

Description.—Test as with genus. Meshwork of cortical shell with tetragonal (often square) and pentagonal pore frames. Surface of shell covered by numerous small spines together with a few larger spines; all spines triradiate in axial section. One large spine radiating out from center of each cupola. Larger triradiate spines connecting with radially arranged beams joining cortical shell to medullary shell.

Remarks.—*Pyramispongia magnifica*, n. sp., is compared to *P. glascocksensis*, n. sp., under the latter species.

magnificus-a-um (Latin, adj.) = splendid, magnificent.

Measurements.—

Specimen	Maximum Width of Test (exclusive of Spines)
Holotype (USNM 165640	200 μ
	Average for holotype and nine paratypes = 229 μ

Type locality.—NSF 591. “Antelope Shale”/“Fiske Creek Formation”. See Locality Descriptions.

Deposition of types.—Holotype = USNM 165640. Paratypes = USNM 165641 and Pessagno Collection, University of Texas at Dallas.

Range.—Early Turonian.

Occurrence.—See Text-figure 3 and Locality Descriptions.

Superfamily **ELLIPSIDIICACEA** HaeckelFamily **DRUPPULIDAE** Haeckel

Type genus. — *Druppula* Haeckel.

Genus **PROTOXIPHOTRACTUS** Pessagno, n. genus

Type species. — *Protoxiphotractus perplexus* Pessagno, n. sp.

Description. — Test ellipsoidal in shape with two massive polar spines. Polar spines varying from equal to unequal in length; one spine often shorter and more massive than other; spines circular to elliptical in axial section lacking grooves and ridges. Cortical shell ellipsoidal with coarse polygonal meshwork; first medullary shell, ellipsoidal in shape with polygonal meshwork; connected to cortical shell by an indeterminate number of radial spines. Second medullary shell spherical in shape; connected to first medullary shell by an indeterminate number of radial bars.

Remarks. — *Protoxiphotractus*, n. gen., differs from *Xiphotractus* Haeckel by possessing polar spines which are circular to elliptical in axial section and lack longitudinally arranged ridges and grooves. It differs further by possessing a second medullary shell which is spherical rather than ellipsoidal in shape.

Protoxiphotractus, n. gen., is tentatively included in the Druppulidae Haeckel. It might be advisable for future workers to include Druppulidae lacking polar spines, possessing one polar spine, or possessing two polar spines in separate subfamilies.

Range. — Jurassic? Upper Cretaceous.

Occurrence. — ?Late Jurassic (Tithonian) of Blake-Bahama Basin; Deep Sea Drilling Project Leg I; Upper Cretaceous of California Coast Ranges.

Protoxiphotractus (?) fischeri Pessagno, n. sp.

Pl. 9, fig. 1

Description. — Test with ellipsoidal cortical shell and at least one ellipsoidal medullary shell. Cortical shell having large pentagonal to hexagonal pore frames. Two polar spines tetra-
radiate in axial section with four longitudinally arranged grooves alternating with four longitudinally arranged ridges.

Remarks. — *Protoxiphotractus (?) fischeri*, n. sp., differs from *Protoxiphotractus perplexus*, n. sp., by having polar spines with

alternating grooves and ridges and by having much coarser mesh-work. Its assignment to *Protoxiphotractus* is questioned because of the structure of its polar spines and because of the character of its medullary shell or shells is unknown.

This species is named for Dr. A. G. Fischer, Department of Geology, Princeton University, in honor of his contributions to Legs 1 and 6 of the Deep Sea Drilling Project.

Measurements — See Text-figure 1 for system of form analysis.

Specimen	AA'	A'S	AS	BB'	cc'	dd'
Holotype (USNM 165626)	100 μ	110 μ	85 μ	110 μ	35 μ	20 μ
Paratypes (USNM 165627)	115 μ	125 μ	95 μ	90 μ	30 μ	20 μ
	100 μ	110 μ	110 μ	110 μ	30 μ	20 μ
	110 μ	95 μ	—	110 μ	35 μ	25 μ
Paratype (Pessagno Coll.)	130 μ	120 μ	110 μ	120 μ	35 μ	30 μ
	120 μ	110 μ	110 μ	110 μ	30 μ	30 μ
	110 μ	140 μ	120 μ	100 μ	40 μ	30 μ
	130 μ	120 μ	100 μ	110 μ	40 μ	40 μ
	110 μ	110 μ	110 μ	110 μ	40 μ	30 μ
	110 μ	70 μ	70 μ	100 μ	30 μ	20 μ

Type locality. — Deep Sea Drilling Project, Leg 1, Site 5A, Core 7, Section 1, (top): Blake-Bahama Basin. Late Jurassic (Tithonian).

Deposition of types. — Holotype = USNM 165626. Paratypes = USNM 165627 and Pessagno Collection, University of Texas at Dallas.

Range. — Late Jurassic (Tithonian); ?Early Cretaceous (Berriasian).

Occurrence. — In addition to its occurrence at its type locality this species has been observed in Late Jurassic (Tithonian) or Early Cretaceous (Berriasian) strata on the west flank of the Shatsky Rise (DSD Leg 6, Site 50, Core 2, Core Catcher; see Fischer, *et al.*, 1971, p. 1114). Recently it has been observed in radiolarian assemblages extracted from a number of Franciscan chert sample.

Protoxiphotractus kirbyi Pessagno, n. sp.

Pl. 14, fig. 6

Description. — Cortical shell ellipsoidal with delicate pentagonal to hexagonal pore frames; primary pore frames developing secondary meshwork comprised of fragile bars usually merging in center and forming five or six secondary frames; secondary frames commonly subtriangular in shape. Polar spines about equal in length; one spine wider proximally.

Remarks. — *Protoxiphotractus kirbyi*, n. sp., has been compared to *P. perplexus* under the latter species.

This species is named after J. M. Kirby in honor of his early contributions to the study of the Great Valley Sequence.

Measurements. — See Text-figure 1 for system of form analysis.

Specimen	AA'	A'S	AS	BB'	cc'	dd'
Holotype (USNM 165618)	130 μ	70 μ	60 μ	85 μ	30 μ	20 μ
Paratypes (USNM 165619)	130 μ	80 μ	65 μ	80 μ	30 μ	20 μ
	130 μ	70 μ	70 μ	80 μ	30 μ	20 μ
Paratypes (Pessagno Coll.)	130 μ	60 μ	50 μ	80 μ	30 μ	20 μ
	120 μ	—	60 μ	80 μ	30 μ	20 μ
	120 μ	—	—	80 μ	—	—
	140 μ	70 μ	70 μ	100 μ	25 μ	25 μ
	150 μ	65 μ	65 μ	100 μ	20 μ	20 μ
	150 μ	50 μ	50 μ	80 μ	20 μ	20 μ
	130 μ	60 μ	50 μ	90 μ	20 μ	20 μ

Type locality. — Holotype from NSF 32-B. Paratypes from NSF 32-B and NSF 134-B. Forbes Formation ("Dobbins Shale Member").

Deposition of types. — Holotype = USNM 165618. Paratypes = USNM 165619 and Pessagno Collection, University of Texas at Dallas.

Range. — Early Campanian.

Occurrence. — See Text-figure 3 and Locality Descriptions.

Protoxiphotractus perplexus Pessagno, n. sp.

Pl. 15, figs. 1-3

Description. — Cortical shell relatively slender, ellipsoidal,

sometimes subcylindrical with massive pentagonal or hexagonal pore frames; pore frames on well-preserved specimens developing internal secondary meshwork comprised of fragile bars which merge in centers of pore frames to form four subtriangular secondary frames. One polar spine wider proximally and usually shorter in length; width of base of spine often equaling one half diameter of test along BB'.

Remarks. — *Protoxiphotractus perplexus*, n. sp., differs from *Protoxiphotractus kirbyi*, n. sp., by possessing a cortical shell which is less ellipsoid and often more slender in shape; by having cortical pore frames which are considerably more massive; and by developing fewer secondary pore frames.

Measurements. — See Text-figure 1 for system of form analysis.

Specimen	AA'	A'S	AS	BB'	cc'	dd'
Holotype (USNM 165616)	130 μ	65 μ	50 μ	80 μ	40 μ	30 μ
Paratypes (USNM 165617)	120 μ	70 μ	40 μ	70 μ	40 μ	25 μ
	130 μ	60 μ	70 μ	80 μ	25 μ	20 μ
	120 μ	70 μ	60 μ	80 μ	20 μ	20 μ
	125 μ	60 μ	60 μ	70 μ	30 μ	20 μ
Paratypes (Pessagno Coll.)	130 μ	50 μ	60 μ	90 μ	35 μ	30 μ
	120 μ	50 μ	65 μ	80 μ	30 μ	20 μ
	130 μ	60 μ	60 μ	90 μ	30 μ	30 μ
	120 μ	90 μ	60 μ	70 μ	30 μ	20 μ
	130 μ	80 μ	60 μ	80 μ	30 μ	30 μ

Type locality. — NSF 32-B. Forbes Formation ("Dobbins Shale" Member). See Locality Descriptions.

Deposition of types. — Holotype = USNM 165616. Paratypes = USNM 165617 and Pessagno Collection, University of Texas at Dallas.

Range. — Early Campanian.

Occurrence. — See Text-figure 3 and Locality Descriptions.

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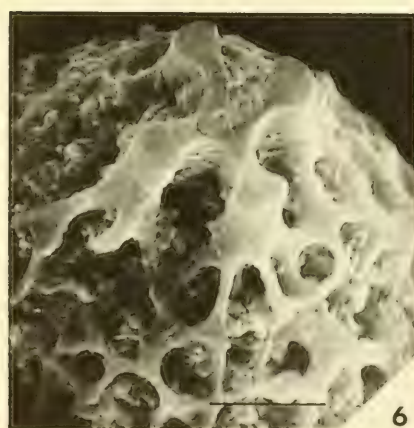
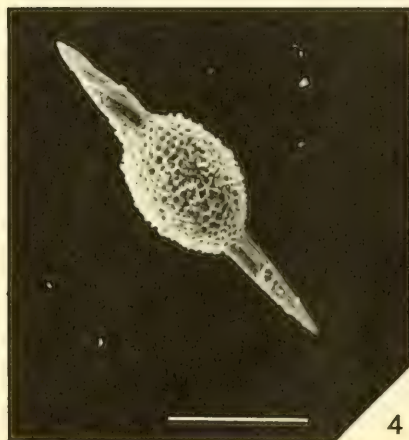
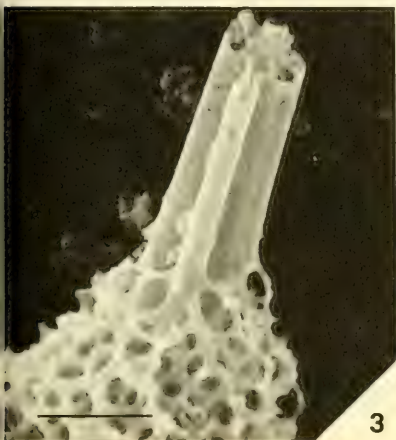
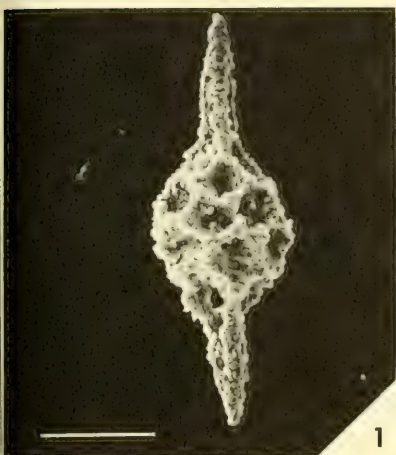
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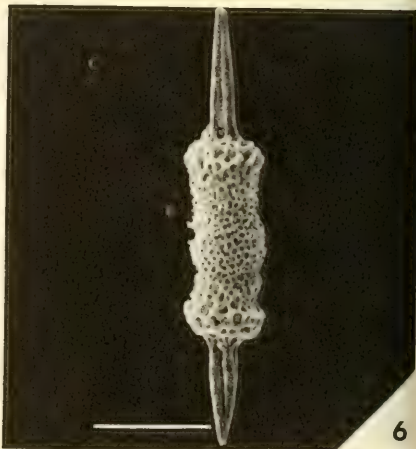
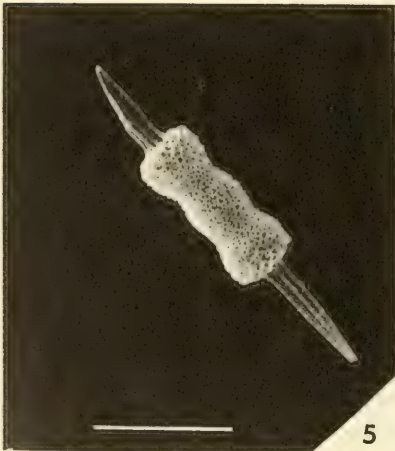
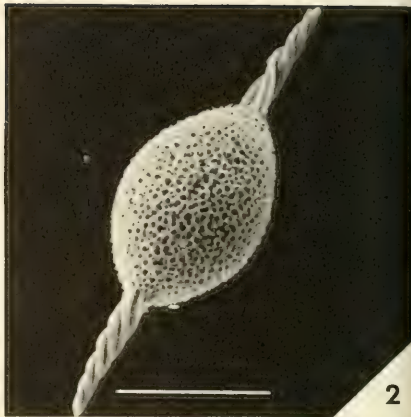
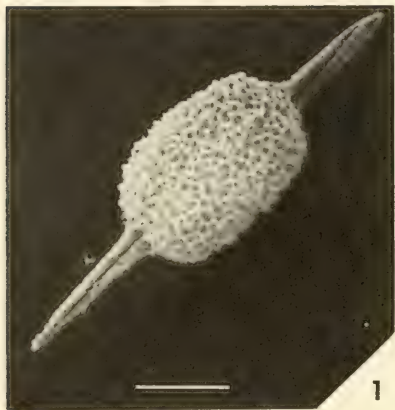
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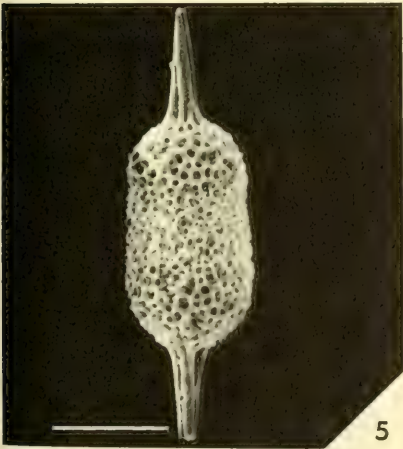
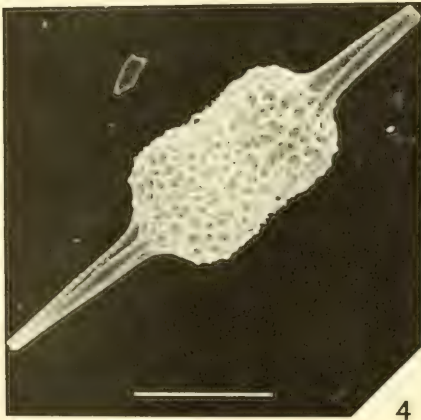
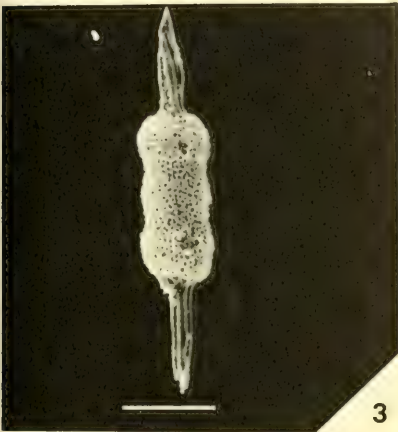
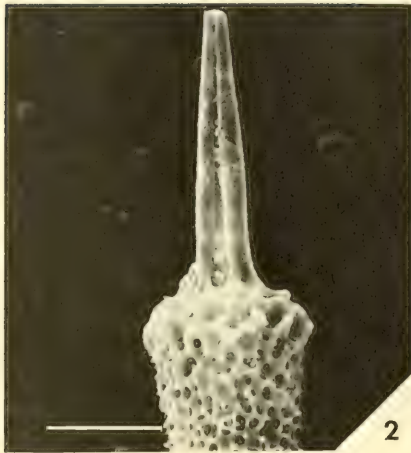
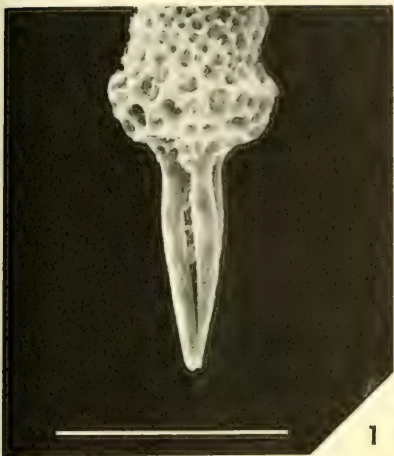


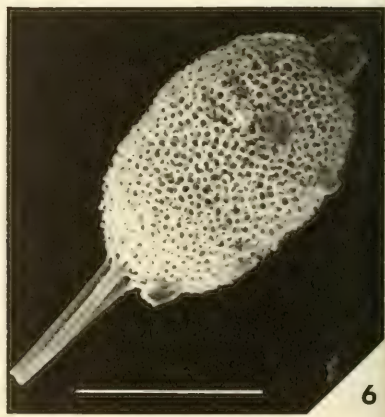
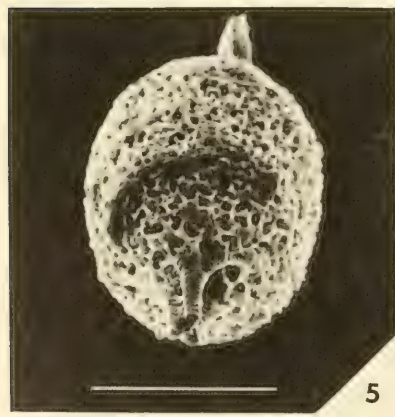
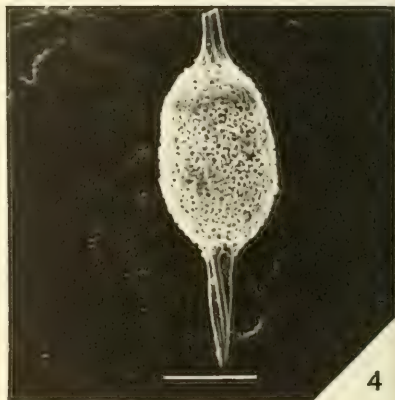
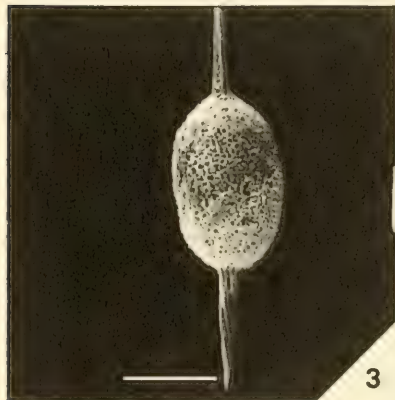
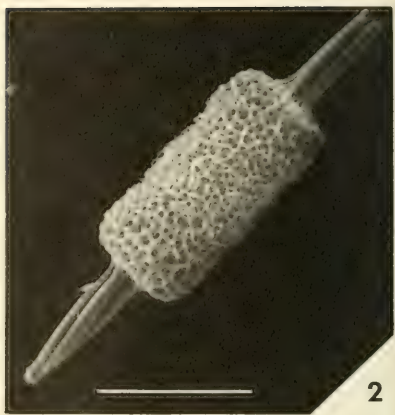
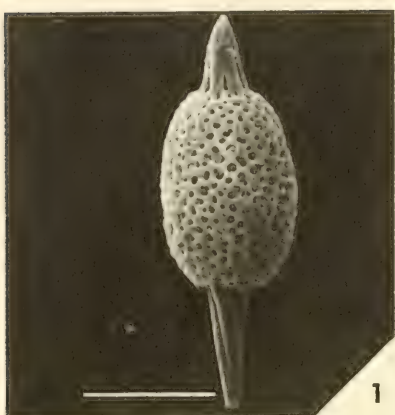
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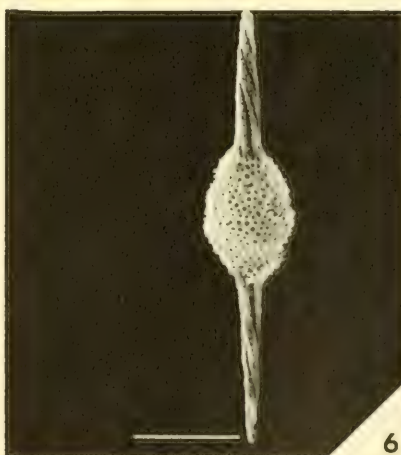
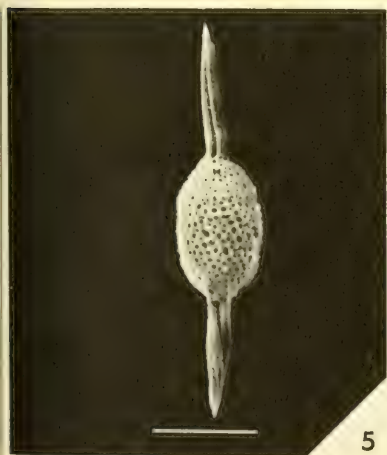
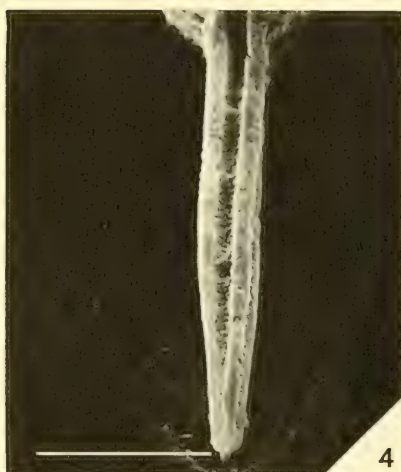
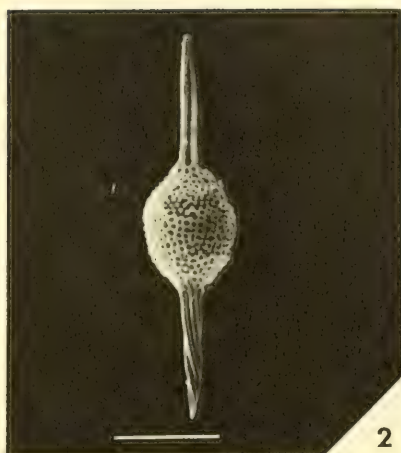
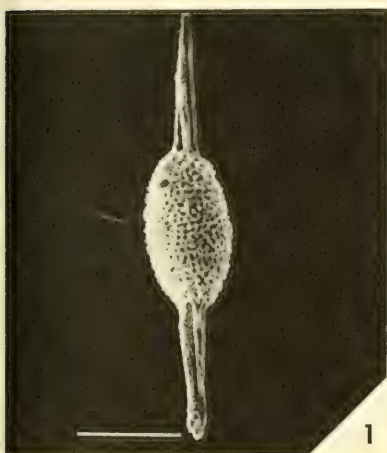


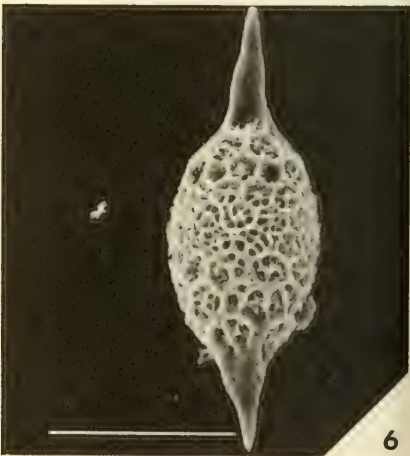
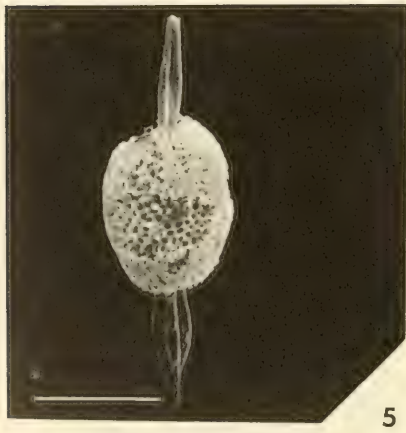
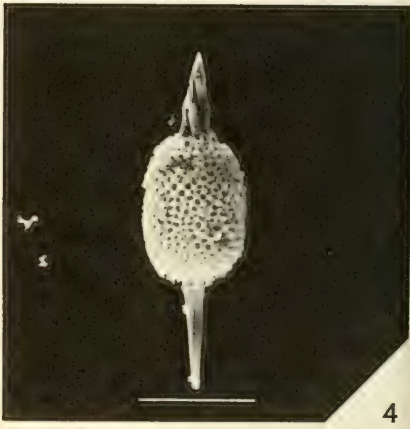
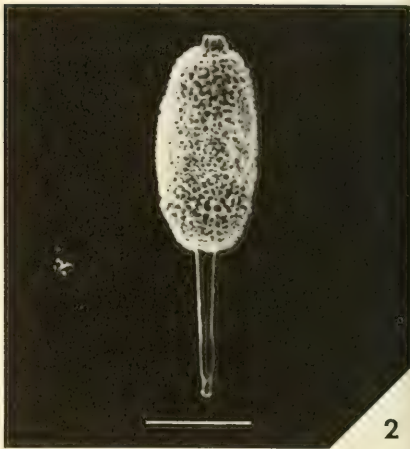
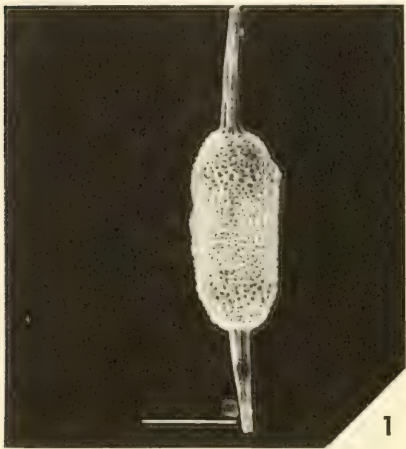
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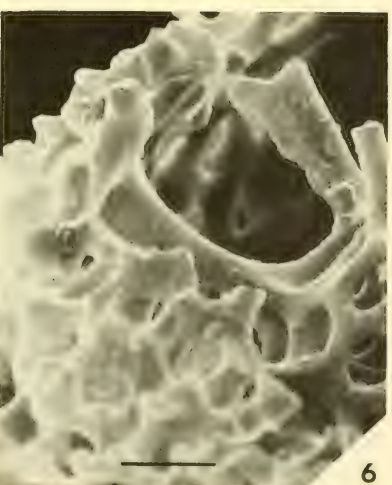
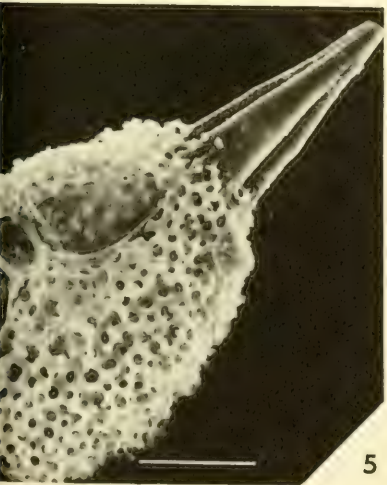
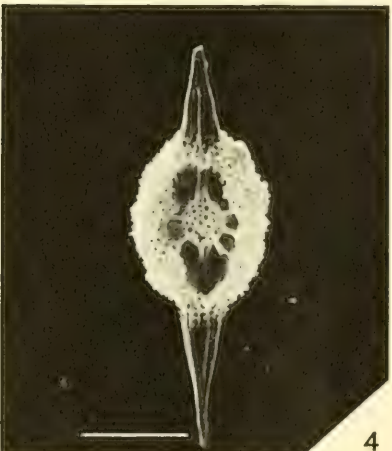
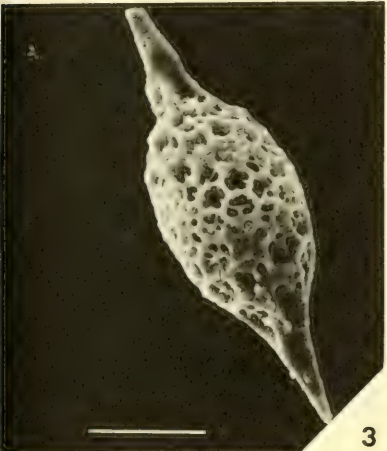
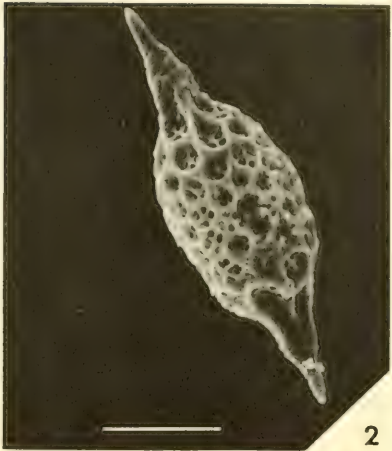
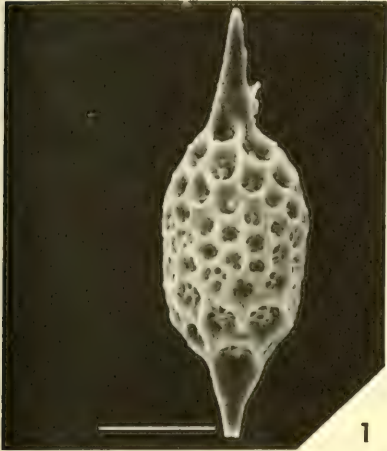


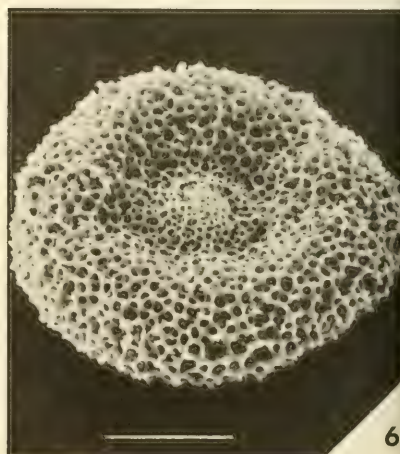
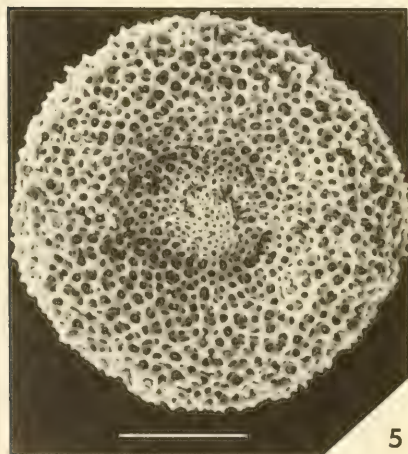
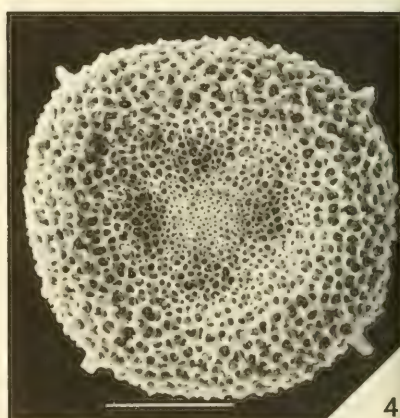
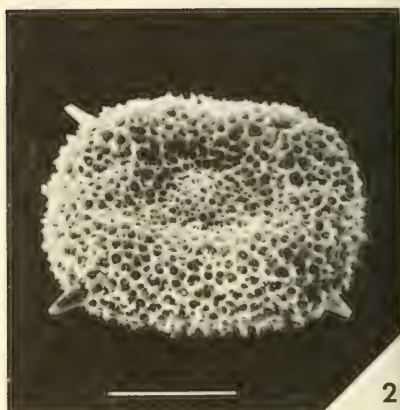
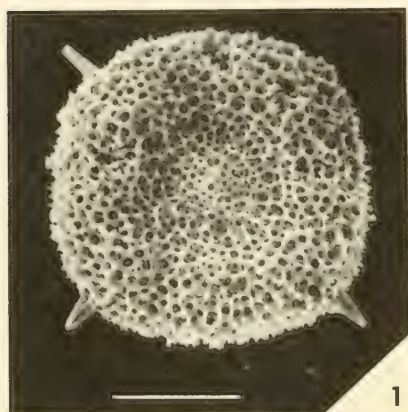
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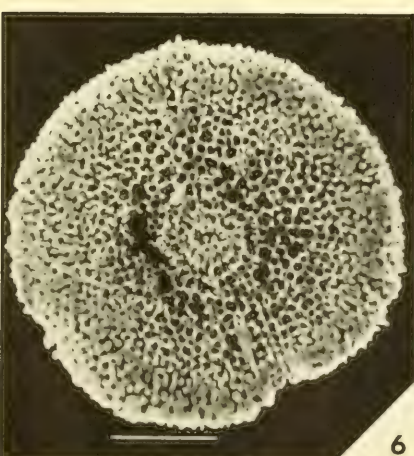
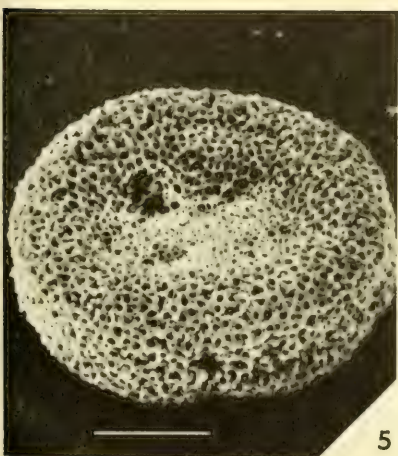
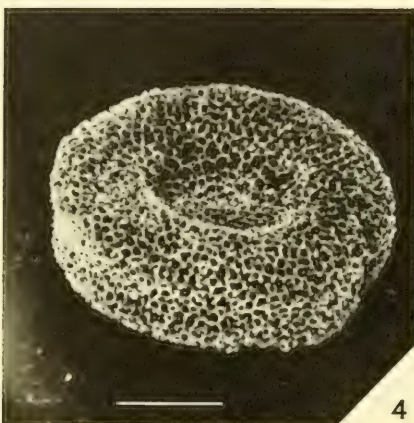
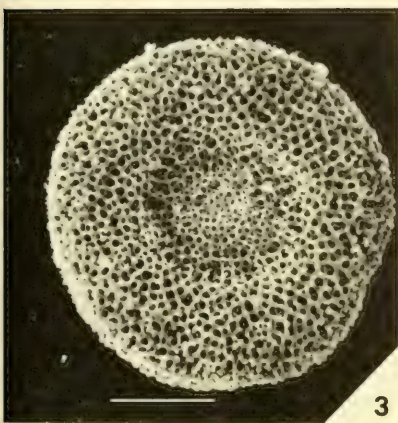
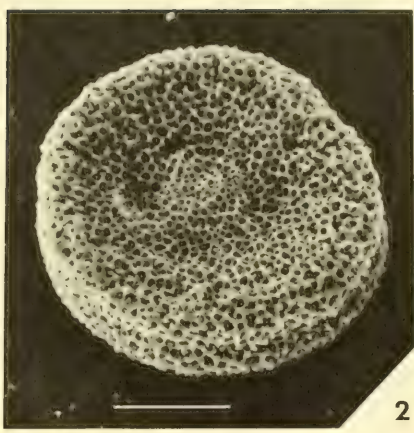
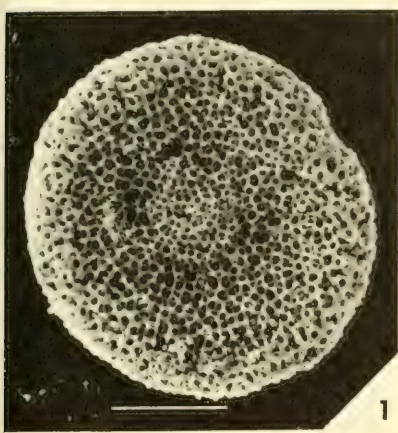


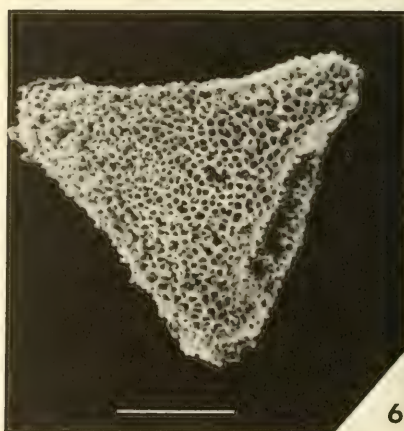
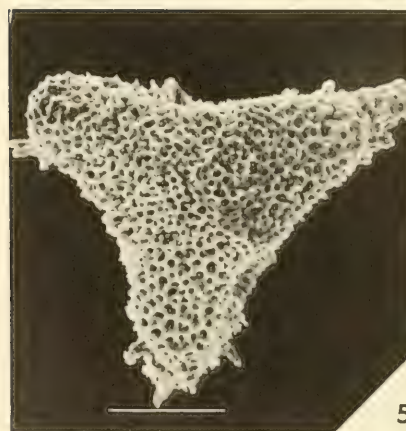
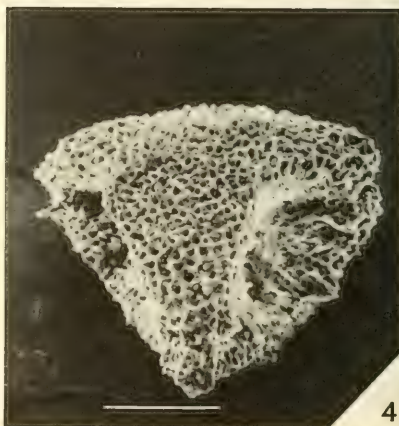
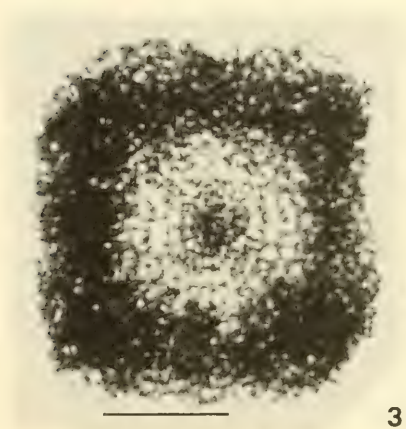
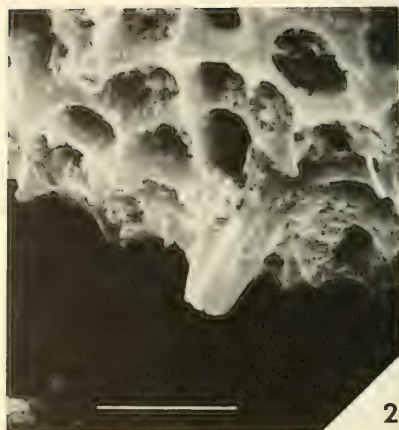
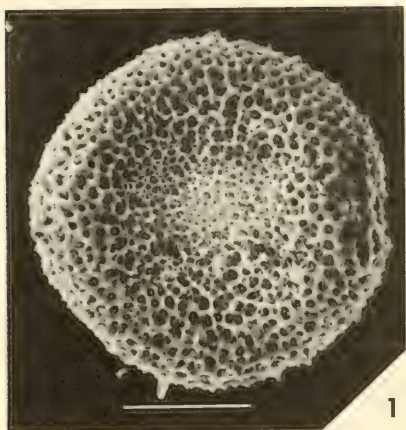
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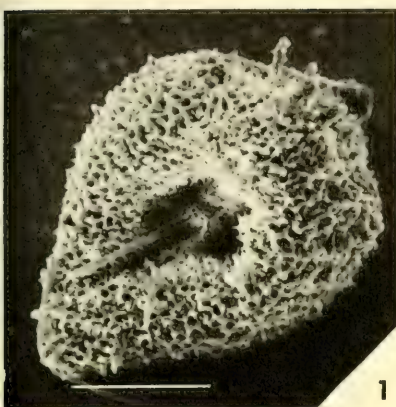


EXPLANATION OF PLATE 18

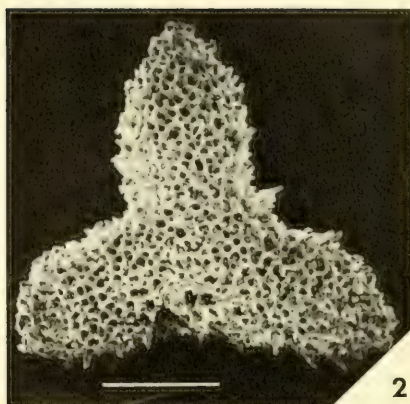
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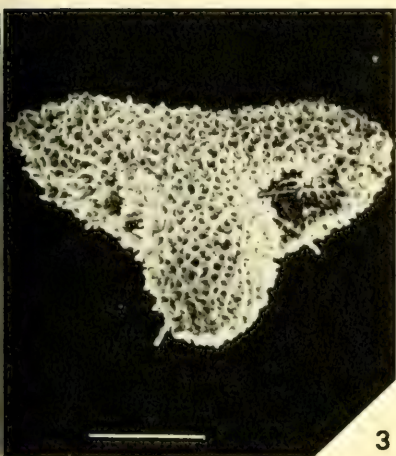
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Holotype (USNM 165642). NSF 591: early Turonian portion of the "Antelope Shale"/"Fiske Creek Formation". Stereo pair. Markers = 100 microns.	



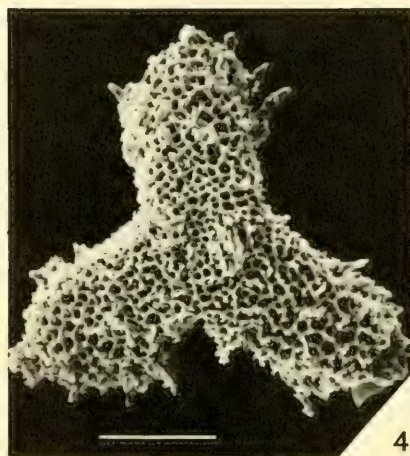
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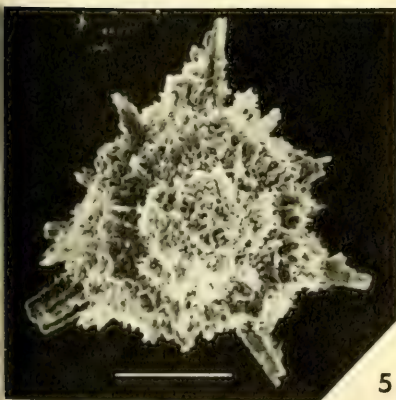
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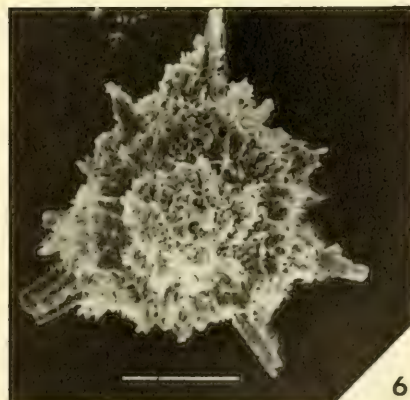
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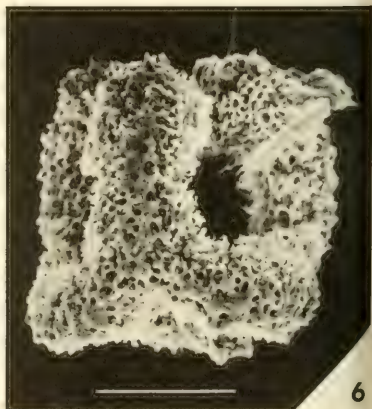
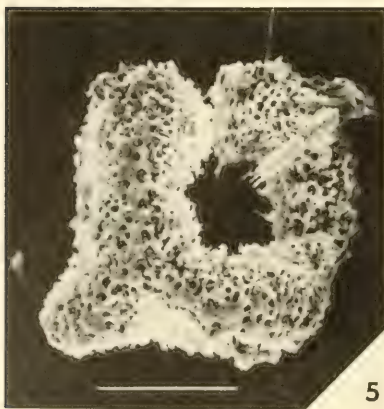
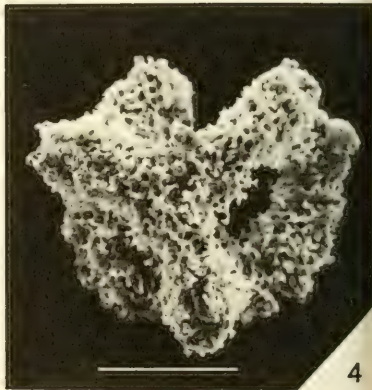
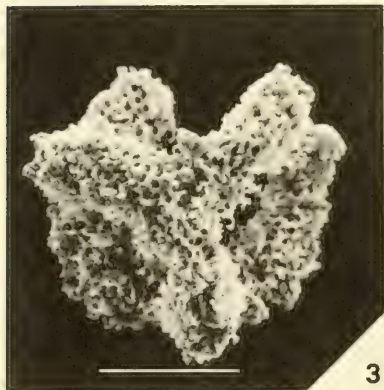
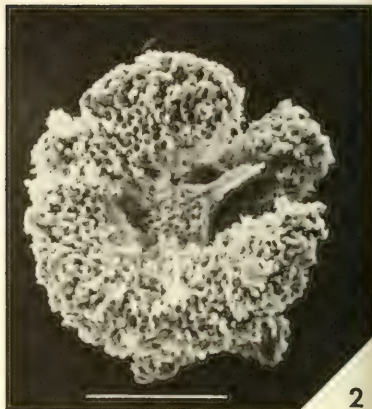
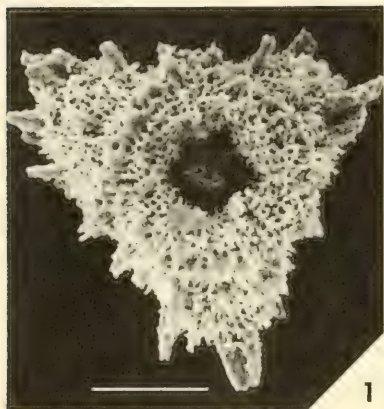
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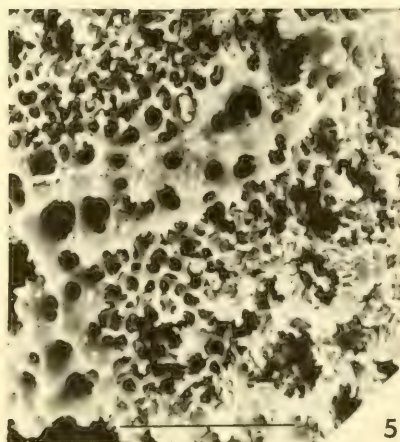
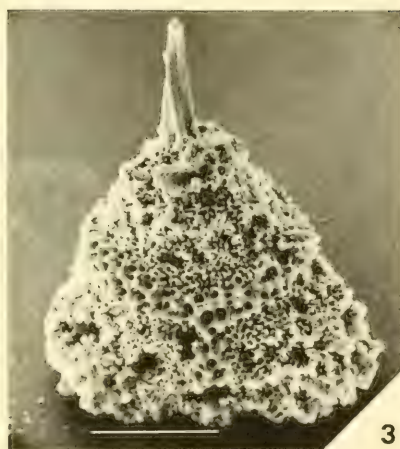
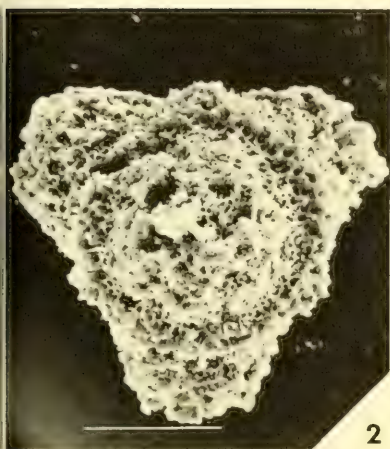
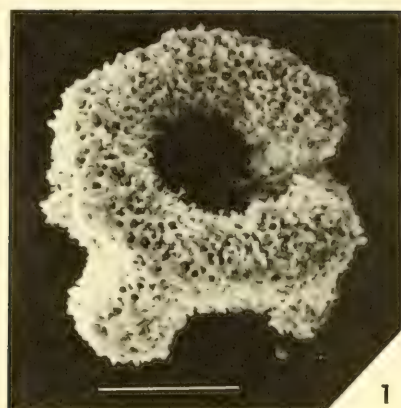


EXPLANATION OF PLATE 20

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EXPLANATION OF PLATE 21

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SAN LUIS POTOSI, MEXICO

By

HARISH M. VERMA

AND

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THE TITHONIAN (JURASSIC) AMMONITE FAUNA
AND STRATIGRAPHY OF SIERRA CATORCE,
SAN LUIS POTOSÍ, MEXICO

HARISH M. VERMA¹

AND

GERD E. G. WESTERMANN

Department of Geology, McMaster University,
Hamilton, Ontario, Canada

ABSTRACT

The Jurassic and Cretaceous of Sierra Catorce, which yielded the molluscan fauna for the first large paleontological monograph on Mexico (Castillo and Aguilera, 1895), comprises from the base: the Oxfordian Huizachal Formation and Zuloaga Limestone and the Kimmeridgian to Tithonian La Caja Formation which is overlain by the Valanginian Taraises Formation. The richly fossiliferous La Caja (≤ 53 m) is divided into two members. The El Pastor Member, below, contains two condensed fossiliferous units, one near the base and one near the top; the El Verde Member, above, has sporadically distributed ammonite fauna.

The taxonomic revision is based on approximately 2,000 specimens from 40 localities including 4 almost complete sections. Only 13 of the 25 species formerly described are valid. Twenty-six species are added to the known Tithonian species of Sierra Catorce. Five species and one subspecies are new: *Virgatospinctes sanchezi*, *Kossmatia purissima*, *Substeuerocheras catorcense*, *Corongoceras cordobai*, *Durangites alencasteri*, and *Substeuerocheras koeneni* (Steuer) *tabulatum*. Of the total of 52 species described here, 20-21 are endemic, 8-9 are in common with Argentina, 5 in common with Europe and 4 in common with the Indo-Malgache region. Many species are dimorphic.

The ammonite fauna is classified into 6 families, 20 genera and 52 species which, with the exception of one Kimmeridgian genus comprising 3 species, are of Tithonian age. Eleven Tithonian genera are recorded for the first time from Sierra Catorce: *Pseudolissoceras* Spath, "*Paraglochiceras*" Collignon, *Pseudoinvoluticeras* Spath, *Virgatospinctes* Uhlig, *Simoceras* Zittel, *Physodoceras* Hyatt, *Substeuerocheras* Spath, *Andiceras* Krantz, *Corongoceras* Spath, *Micracanthoceras* Spath and *Durangites* Burckhardt. On the basis of abundant new material, the genera *Substeuerocheras*, *Kossmatia* and *Durangites* are discussed in detail. "*Parodontoceras*" Spath is a synonym of *Substeuerocheras*; *Kossmatia* is transferred from the family Ataxioceratidae (cf. Treatise) to the Berriasellidae; *Durangites* may be dimorphic.

Four major ammonite assemblages are recognized: (1) the small Kimmeridgian *Idoceras* assemblage near the base of the El Pastor Member, (2) the diverse late Lower ("Middle") Tithonian *Virgatospinctinae* assemblage in the upper El Pastor Member, (3) the early Upper Tithonian *Kossmatia-Durangites-Corongoceras* assemblage in the lower El Verde Member, and (4) the late Upper Tithonian *Substeuerocheras-Berriasella* assemblage in the upper El Verde Member. There is close affinity at generic and specific levels with Tithonian faunas especially of Argentina: the condensed *Virgatospinctinae* Beds are correlated with the two Argentine zones of *Virgatospinctes mendozanus* and *Pseudolissoceras zitteli*; the *Kossmatia-Durangites-Corongoceras* assemblage is in part equivalent to the Argentine Zone of *Corongoceras alternans*; and the *Substeuerocheras-Berriasella* assemblage belongs to the *Substeuerocheras koeneni* Zone. Mediterranean affinities appear to be secondary. Boreal elements are missing.

On account of high clastic content, the abundance of benthos, and the impoverishment of compressed involute forms among the ammonites, the La Caja Formation appears to have been deposited in shallow, moderately off-shore waters.

¹ Present address: Dept. of Invertebrate Palaeontology, Royal Ontario Museum, Toronto, Ontario, Canada. This work constitutes the revised doctoral thesis of H. M. Verma, submitted to McMaster University in partial fulfillment of the requirements for the Ph.D. degree (May, 1972).

FAUNA DE AMONITAS Y ESTRATIGRAFÍA DEL TITÓNICO (JURÁSICO) DE SIERRA CATORCE, SAN LUIS POTOSÍ, MÉXICO

por

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Departamento de Geología, McMaster University,
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RESUMEN

El Jurásico y Cretáceo de la Sierra Catorce, de donde provino la fauna de moluscos para la primera monografía paleontológica de México (Castillo y Aguilera, 1895), comprende, desde la base: La Formación Huizachal, y Caliza Zuloaga, oxfordianas y la Formación La Caja, kimmeridgiana a titoniana, que infrayace a la Formación Taraises, valanginiana. La Caja (≤ 53 m) abundantemente fosilífera, es dividida en dos miembros. El Miembro El Pastor, abajo, contiene dos unidades fosilíferas condensadas, una cerca de la base y otra cerca del techo; el Miembro El Verde, arriba, contiene una fauna de amonitas distribuida esporádicamente.

La revisión taxonómica se basa en aproximadamente 2,000 especímenes de 40 localidades, incluyendo 4 secciones estratigráficas casi completas. Sólo 13 de las 25 especies previamente descritas son válidas. Veintiseis especies son agregadas a las especies titónicas de Sierra Catorce. Cinco especies y una subespecie son nuevas: *Virgatosphinctes sanchezi*, *Kossmatia purissima*, *Substeueroceras catorcense*, *Corongoceras cordobai*, *Durangites alencasteri*, y *Substeueroceras koeneni* (Steuer) *tabulatum*. Del total de 52 especies descritas en este trabajo, 20-21 son endémicas; 8-9 son comunes a Argentina, 5 comunes a Europa y 4 comunes a la región Indo-Malgache.

La fauna de amonitas es clasificada en 6 familias, 20 géneros y 52 especies que, con la excepción de un género kimmeridgiano que comprende tres especies, son de edad titónica. Once géneros titónicos son señalados por primera vez para la Sierra Catorce: *Pseudolissoceras* Spath, "*Paraglochiceras*" Collignon, *Pseudoinvoluticeras* Spath, *Virgatosphinctes* Uhlig, *Simoceras* Zittel, *Physodoceras* Hyatt, *Substeueroceras* Spath, *Andiceras* Krantz, *Corongoceras* Spath, *Micracanthoceras* Spath y *Durangites* Burckhardt. Sobre la base de abundante material nuevo, los géneros *Substeueroceras*, *Kossmatia*, y *Durangites* son discutidos en detalle. "*Parodontoceras*" Spath es un sinónimo de *Substeueroceras*; *Kossmatia* es transferida de la familia Ataxioceratidae (cf. Treatise) a Berriasellidae; *Durangites* parece ser dimórfico.

Cuatro conjuntos principales de amonitas son reconocidos: (1) El pequeño conjunto kimmeridgiano de *Idoceras* cerca de la base del Miembro El Pastor, (2) el conjunto diverso de *Virgatosphinctinae* del Titónico Inferior tardío ("Medio") en la parte superior del Miembro El Pastor, (3) el conjunto de *Kossmatia-Durangites-Corongoceras* del Titónico Superior temprano en la parte inferior del Miembro El Verde, y (4) el conjunto de *Berriasella-Substeueroceras* del Titónico Superior tardío en la parte superior del Miembro El Verde. Hay una afinidad estrecha al nivel genérico y específico con faunas titónicas, especialmente de Argentina: Las capas condensadas con *Virgatosphinctinae* son correlacionadas con las dos Zonas argentinas de *Virgatosphinctes mendozanus* y *Pseudolissoceras zitteli*; el conjunto de *Kossmatia-Durangites-Corongoceras* es parcialmente equivalente a la Zona argentina de *Corongoceras alternans*; y el conjunto de *Substeueroceras-Berriasella* pertenece a la Zona de *Substeueroceras koeneni*. Las afinidades mediterráneas parecen ser secundarias. No hay elementos boreales.

A juzgar por el contenido de clastos más bien alto, la abundancia de fósiles bentónicos y la escasez de formas involutas comprimidas entre las amonitas, la Formación La Caja parece haber sido depositada en aguas más bien someras y moderadamente lejanas a la costa.

INTRODUCTION

The earliest detailed paleontological study of the Jurassic molluscan fauna of Mexico was reported in a monograph published in 1895 by Antonio del Castillo (then Director, Comisión Geología de México) and José G. Aguilera (then Paleontologist). The study was based upon a collection of mainly late Jurassic ammonites, brachiopods, and bivalves from Sierra Catorce (also known as Sierra de Catorce), a small mountain range on the western margin of the Sierra Madre Oriental in the northern part of the State of San Luis Potosí, north-central Mexico. The fossils described by these authors included in particular a large variety of moderately well-preserved ammonites; out of 40 described species, 26 were reported as new. However, the illustrations were poor and stratigraphic data almost absent. Consequently, for nearly 80 years, students of Upper Jurassic Mollusca have found it extremely difficult to use this pioneering monograph.

Since the beginning of this century, the Jurassic and Cretaceous ammonite faunas of other parts of Mexico have attracted the attention of several paleontologists, notably Carl Burckhardt, Ralph W. Imlay, and Heinrich K. Erben.

Without doubt, the greatest contribution to our present knowledge of the stratigraphy and faunas of these two systems has been made by Burckhardt. This distinguished Swiss paleontologist spent nearly 30 years mapping, collecting, and describing invertebrate fossils from many distant outcrops, mainly in northern Mexico. Several large and profusely illustrated monographs since 1906 (see reference list) bear testimony to his efforts to lay down the basic framework of the geology and paleontology of these areas. To this day, one can find the trenches dug by his work crews mainly for the systematic collection of fossils and partly for the investigation of phosphate deposits.

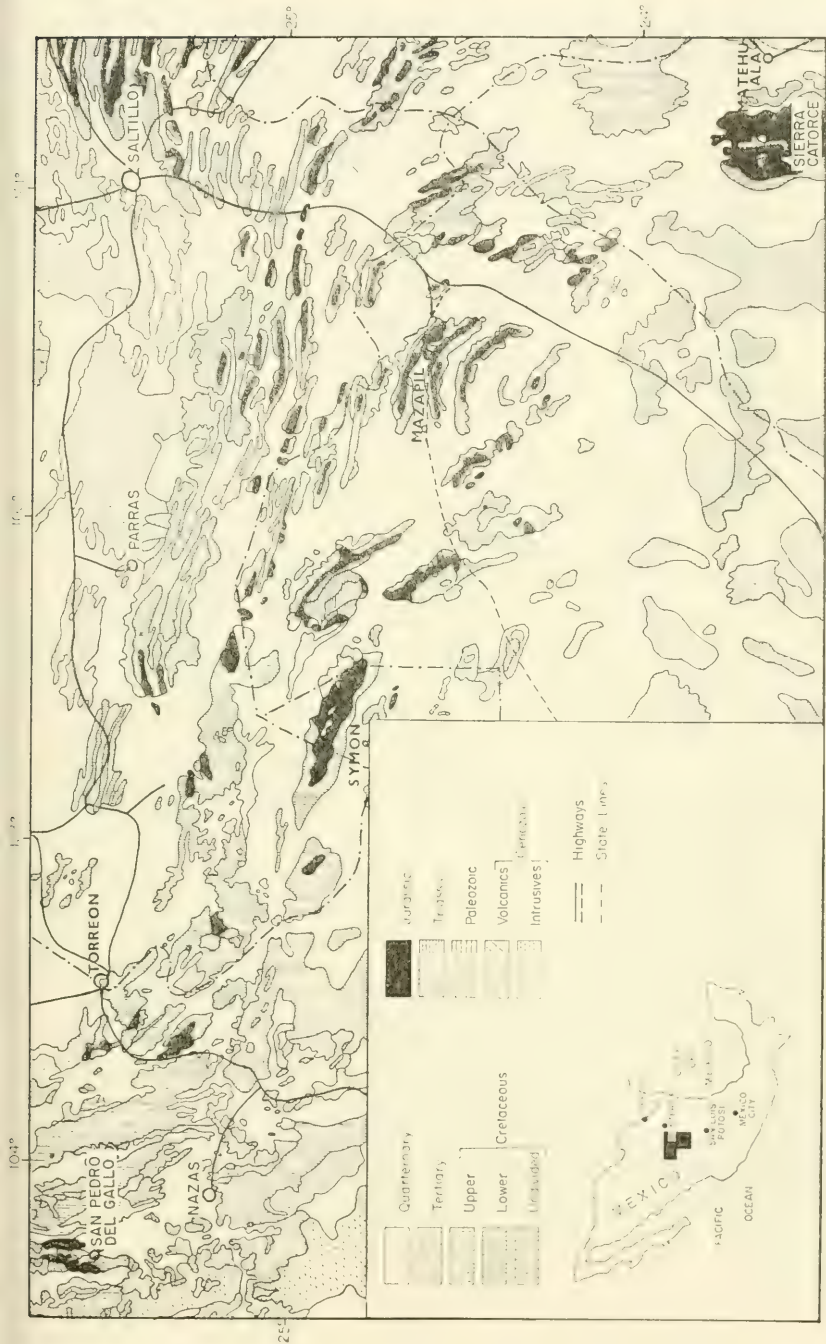
Ralph W. Imlay, of the United States Geological Survey, resumed the work initiated by Burckhardt as is evident from a series of publications beginning in 1936 (see reference list). He investigated the adjacent unexplored areas, reconstructed the paleogeographic history of the Mexican Mesozoic geosyncline, and correlated the Jurassic formations with the rest of the North American Jurassic.

Subsequent work by H. K. Erben (see reference list) was restricted to the Lower and Middle Jurassic.

Several factors necessitated the revision of the ammonite fauna of Sierra Catorce. The most important was the lack of stratigraphic information about the large number of allegedly new ammonite species named by Aguilera in Castillo and Aguilera (1895)²; all were said to be "Portlandian-Kimmeridgian". The 40 species of which 38 are Jurassic with 25 "new", have remained more poorly known than those described by Burckhardt from the more northerly areas of Mazapil in Zacatecas (Burckhardt, 1906) and San Pedro del Gallo (Burckhardt, 1912) and Symon in Durango (Burckhardt, 1919-21) (Text-fig. 1). Aguilera's classification is obviously in urgent need of revision, not only at the genus-group but also at the species-group level, because many of the alleged species seem to fall within the limits of infra-specific variation. The re-examination of the type area was also expected to result in the discovery of additional taxa, locally, regionally or entirely new, through more complete sampling from the old and many new localities. The Sierra Catorce, furthermore, offers excellent conditions for field work, particularly in the latter part of summer when this area is dry and temperatures are moderate. Although access to some localities is somewhat arduous, exposures are exceptionally good.

The field work was carried out almost entirely by Verma during the summers of 1968 and 1969 for a period of about ten weeks. It was restricted to the stratigraphy and structure of the exposed outcrops and the systematic collection of fossils and rock samples from a number of sections. Detailed geological mapping of the area was ruled out because a large-scale topographic map was not available. Although aerial photographs of some parts of Sierra Catorce were available (Cia. Mexicana Aerofoto, agricultural survey of 1960), they were considered unsatisfactory for this work because of their small scale and exclusion of areas with important outcrops. The general reconnaissance of the area revealed immediately that, of all the formations exposed, the Upper Jurassic

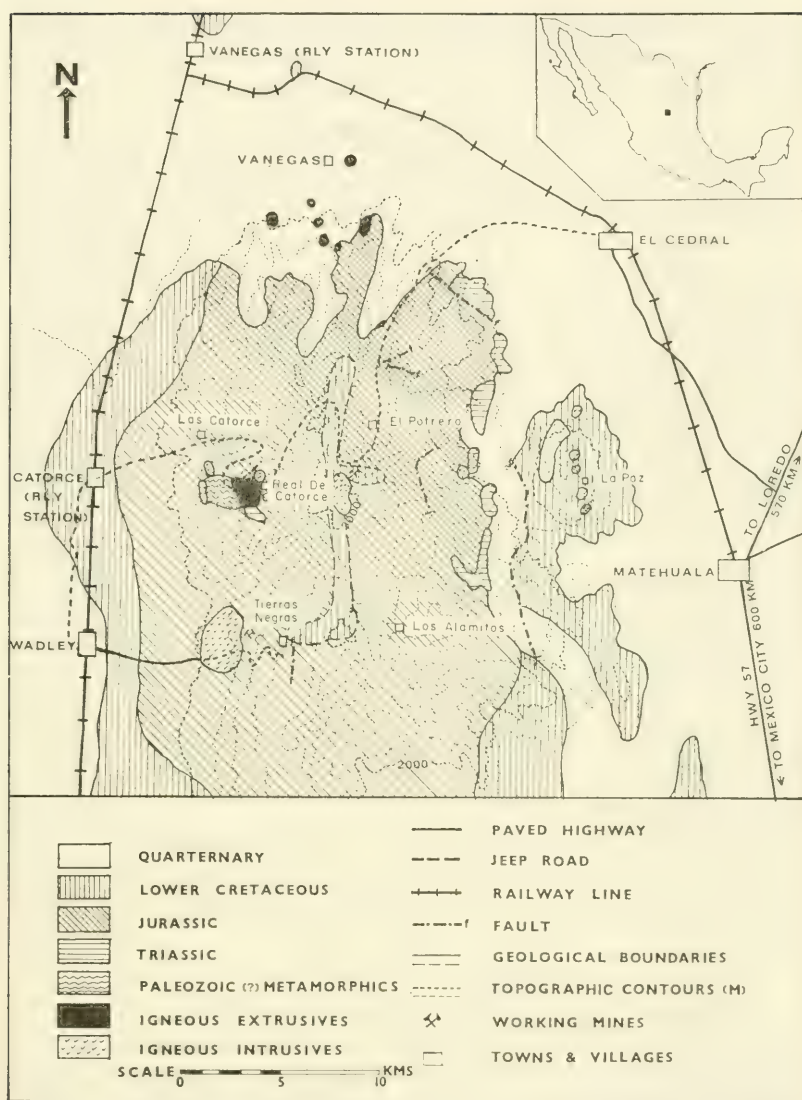
² The fossil descriptions and new names in the work of Castillo and Aguilera (1895) are here being credited to Aguilera who was the paleontologist. The labels accompanying the type specimens in Instituto de Geología, Universidad Autónoma de México, also indicate Aguilera's sole authorship.



Text-fig. 1. — Geological map of north-central Mexico. The Sierra Catorce is in the southeast corner, (slightly modified after Carta Geologica de la Republica Mexicana, 1968, scale 1:2,000,000).

La Caja Formation contained the greatest abundance of invertebrate fossils; the underlying Huizachal Formation showed only impressions of indeterminable ammonites; and the overlying Taraises Formation yielded a small number of internal moulds of Valanginian ammonites. Attention was, therefore, focused on the La Caja from which rich collections, mainly of ammonites and pelecypods, were made. A small number of belemnites, aptychi, gastropods, brachiopods, and vertebrae of marine reptiles is also included in the collection. This work embodies the results of the research on the ammonites; the Bivalvia are presently under investigation by Dra. Gloria Alencáster of the Instituto de Geología, Universidad Nacional Autónoma de México.

The Sierra Catorce is a small range of mountains at latitudes $23^{\circ}27'$ to 45°N and longitudes $100^{\circ}45'$ to 101°W (Text-fig. 1). The western half of the Sierra has steep slopes and deep gullies while the topography on the eastern side is characterized by gentle slopes and long, wide valleys. The water divide runs approximately north-south through the middle of the Sierra. The many varieties of cacti and brush, found in this region, are typical of semidesert vegetation. In the west-central part of the Sierra, at an elevation of 2,757 m, lies the ancient mining town of Real de Catorce which has attracted many geologists, including paleontologists, in the past and was Verma's base camp during the field work. Access is by rough road either from the east, through the town of Matchuala, or from the west, through Estación Catorce which is connected to Mexico City by railway. Matchuala is situated about 600 km north-northwest of Mexico City on Highway 57. A distinction should be made between the three towns of Estación Catorce, Las Catorce, and Real de Catorce (Text-figs. 2, 9). From Real de Catorce, almost all the fossiliferous localities (Table 1) can be reached by foot; they are named with reference either to the proximate village or mine. Presently only two mines are working in the area; the Santa Ana Silver mine near the village of La Luz and a mercury mine near the village of Tierras Negras, about 10 km south of Real de Catorce. El Pastor, the southernmost locality studied, is about five hours on foot from Real de Catorce but can also be reached in two hours by jeep via Estación Catorce and Estación Wadley.



Text-fig. 2. — Geological map of the Sierra Catorce, northern part, (modified after Carta Geologica de la Republica Mexicana, 1968, scale 1:500,000).

This work constitutes the revised doctoral thesis of Verma, submitted to McMaster University in partial fulfilment of the requirements for the Ph.D. degree (May, 1972).

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PREVIOUS WORK

Because of the silver mineralization, the Sierra Catorce received early attention by geologists³ some of whom included in their descriptions brief references to the stratigraphy and mollusc fossils. The first scientific report on the Sierra is credited to Joseph Burkart (1836; not to be mistaken for the later Carl Burckhardt).

³ In a recent book entitled "The Incredible City", Lucy Wallace (1965), a Texas journalist, has tried to rejuvenate interest in the mining history and culture of Real de Catorce with the help of some old pictures and municipal records.

Based on a few fragments including bivalves, a crinoid, a gastropod, and an ammonite collected by him and identified by the noted German paleontologist, Professor Goldfuss, Burkart was, however, misled to believe that the fossiliferous beds were of Carboniferous age. Baron Alexander von Humboldt (1840, *vide* Castillo and Aguilera, 1895), also from Germany, appears to be the first to report on the mineralization, but Humboldt never visited the area according to Baker (1922).

Saint-Clair-Duport (1843) gave the first description of the anticlinal structure and of the stratigraphy of the Sierra; "quartzose sandstones" [La Caja Formation] were recognized to be underlain and overlain by limestones and to include basaltic and porphyritic dykes. Laur (1871) improved on the earlier works by reporting the first evidence for Upper Jurassic beds in the Sierra Catorce, and, indeed, for the whole of Mexico, based on identifications by Professor Bayle, France, of "*Ammonites transitorius*, *A. plicatilis*, *A. priasensis*, and *Aptychus latus*".

After the discussion of some bivalves, mainly *Buchia* [*Aucella* auct.], from Sierra Catorce by Nikitin (1890), the pioneer work on the Jurassic ammonites was published by Castillo and Aguilera (1895) which is discussed in detail below. Pavlow (1907) and Sokolov (1908) again commented on bivalves only.

The geology of Sierra Catorce was later described by Baker (1922) who divided the sedimentary rocks of the area into eight units. His units 1 to 3 comprise what is here referred to as Huizachal Formation; his unit 4 is here identified with the Zuloaga Limestone; unit 5 with the La Caja Formation; and units 6 to 8 with the Taraises Formation. Baker assigned an Upper Jurassic age to his units 4 to 7, and a Lower Cretaceous age to his unit 8. He also noted the existence of several faults in the area, some of which are described in the present work.

While similar faunas in adjacent parts of the Mexican geosyncline, *i.e.* Mazapil, San Pedro del Gallo, and Symon, were extensively described in the excellent works of Burckhardt (see reference list), the fauna and biostratigraphy of the Sierra Catorce have never been re-examined and remained almost unknown. Castillo and Aguilera's work suffered from three main shortcomings. Firstly, no stratigraphic sections were described and, therefore,

little information is available regarding the faunal successions and stratigraphic levels. All fossils were simply reported to be from the "Kimmeridgian and Portlandian". Secondly the fossil localities were merely identified with the names of proximate villages or "Arroyos" or "Ranchos"; since there are now several natural outcrops in or around each of these localities, and since the same was probably true in the past, it is not possible to pinpoint the exact localities. Finally, the type specimens were mostly fragmentary and ill prepared, while the illustrations accompanying the meager descriptions were extremely poor. Aguilera (*in* Castillo and Aguilera, 1895) described what he believed were 40 species (38 Jurassic) of ammonites, 26 (25 Jurassic) of which were under new names. Burckhardt (1930) revised the generic assignment of 15 of these "species" and added 3 from a collection made by Fernandez from the same general area. Imlay (1939) compiled a list of ammonites from north-central Mexico in which he mentioned only 11 of Aguilera's "species", mostly under different genera. Although Burckhardt and Imlay (*ops. cit.*) did not discuss the reasons for the generic transfers, most of them were correct; the original species descriptions appeared under such non-Jurassic genera as *Rhacophyllites* and *Hoplites* (Table 2, p. 146).

In the concluding part of their monograph, Castillo and Aguilera divided the Sierra Catorce sequence into 3 units (from top):

3. Ash-grey compact siliceous limestones with nodules of black silica—? Aptian-Albian.
2. Sandstones, marly shales and clays. Fossiliferous — Upper Jurassic, Lower Cretaceous.
 - (a) "Cieneguita Beds (With *Lytoceras* sp., *Phylloceras* sp., *Mazapilites* sp., *Olcostephanus* sp.)
 - (b) "Los Alamitos Beds" (With *Haploceras* spp., *Kossmatia* spp., *Aulacosphinctes* spp., *Aulacosphinctoides* spp., *Idoceras* sp., and many brachiopod and bivalve species especially *Buchia* spp.)
1. Glossy slates and phyllites. Unfossiliferous.

Burckhardt (1930) pointed out that this alleged sequence contained many inconsistencies, *i.e.* the occurrence of "Upper Port-

landian" *Kossmatia* together with the "Middle and Upper Kimmeridgian" *Idoceras* in the supposed Los Alamitos Beds, and the occurrence of "Lower Portlandian" *Mazapilites* with the Valanginian *Olcostephanus* in the supposed Cieneguita Beds. Burckhardt (*op. cit.*, p. 79), therefore, proposed that these subdivisions be abandoned because they were incompatible with the stratigraphic distribution of ammonites in northern Mexico and rearranged the Sierra Catorce fauna to fit into his scheme. It appears that Castillo and Aguilera had little stratigraphic data and that their scheme was mainly inferred from paleontological considerations. The new field work by Verma has confirmed that their subdivisions are inconsistent with the fossil record. Moreover, the "Los Alamitos Beds" and "Cieneguita Beds" were defined neither lithologically nor by accurate locality; both Los Alamitos and Cieneguita have different exposures yielding Lower to Upper Tithonian fossils.

STRUCTURE AND STRATIGRAPHY

The Sierra Catorce is the southern extension of a curved folded belt of thick Cretaceous and Jurassic sediments extending from the state of Durango to the State of San Luis Potosí. The sediments are tightly folded in the form of an anticlinorium describing a northerly to northeasterly convex arch, apparently part of an orocline. The isolated Jurassic outcrop of Sierra Catorce is probably bounded on all sides by thrust faults and consists of an anticlinorium plunging in the north and south, and flanked in the east and west by Cretaceous rocks. The dips within the synclines and anticlines vary from gentle to almost vertical. The structure is further complicated by the many high-angle thrust faults. There are numerous intersecting porphyritic dykes, often intruded along a fault plane. The associated mineralization (silver, antimony, mercury) gave rise to a large number of mines in the area, most of which have been abandoned. Small outcrops of Tertiary basalts and Paleozoic to possibly early Jurassic metamorphic sediments also occur in the Sierra.

In the marine Upper Jurassic of northern Mexico, two facies have been distinguished, one near-shore and the other off-shore. In the near-shore facies near Mazapil, approximately 150 km north of Sierra Catorce, the early Upper Jurassic rocks directly overlying

the red and grey beds of the Huizachal Formation comprise the La Gloria and La Casita Formations (Imlay, 1936). The La Gloria consists of sandstones and conglomerates and in some sections thick-bedded limestones; the La Casita is characterized by conglomerates, sandstones, shales, marls, limestones, and some gypsum and coal.

The off-shore equivalents of the La Gloria and the La Casita Formations, which are developed in the Sierra Catorce, are the Zuloaga Limestone and La Caja Formation, respectively. They are overlain by the Cretaceous Taraises Formation which consists mostly of limestones. The La Caja Formation bears the ammonite fauna described herein.

HUIZACHAL FORMATION

This formation was named by Imlay (1948, p. 1753) for up to 300 m of dark red to yellow claystones and siltstones, usually even-bedded, partly cross-bedded, locally grading into anhydrite; a basal conglomerate is present. The type section is at the southwest side of Huizachal Valley, near the head of Arroyo Juan Capitán, approximately 20 km south-southwest of Victoria in Tamaulipas. The environment of deposition, although uncertain, was probably continental. The lack of fossils and local anhydrite suggest superhaline conditions, probably at least in part of an inland basin (Imlay, 1943, 1948).

Lower Part: red beds. — In the Sierra Catorce, the lower Huizachal Formation consists of approximately 30 m interbedded dark red shales and siltstones with an average thickness of about 0.6 m. These are best observed in the hills bordering the village of Real de Catorce (Pl. 22, fig. 1). Occasionally, fracture cleavage and thin (≤ 3 cm) calcite veins are present. Good exposures are along the mule track leading northeast from Real de Catorce to the San Andres mine. The beds are unfossiliferous (macrofossils).

A thin section of red siltstones from the San Andrés mine section consists mostly of clay minerals in a matrix of hematite. A few coarse angular quartz grains and some muscovite grains are also present.

Upper Part: grey shales. — Overlying the red beds are about 200 m of greyish-white fissile calcareous shales which are also well exposed on the slopes surrounding Real de Catorce (Pl. 22, fig. 1).

The shales are friable and have invariably developed cleavage oblique to the bedding. Thin (10-15 cm) veins of calcite are present within a bed, between beds, or cutting several beds obliquely. These shales are also barren of macrofossils. The grey shales have been placed in the Huizachal Formation and are considered as a facies of the upper Huizachal, reflecting modified conditions of sedimentation and source area. Along the mule track leading from Real de Catorce to the San Andres mine at about 0.25 km from Real de Catorce, the red beds are in fault contact with the grey beds. Just above the new cemetery the red shales in the northern block have been downfaulted approximately 60 m.

ZULOAGA LIMESTONE

The formation was named by Imlay (1938, p. 1657) for 50 to 550 m thin-bedded grey limestones. The type section is north of Melchor Ocampo in the Sierra Sombrerete, Coahuila.

Following the grey shales of the Huizachal conformably is the Zuloaga Limestone which is exposed, nearly 200 m thick on or near the tops of the hills surrounding Real de Catorce. The best section is located along the jeep road from Real de Catorce to the El Compromiso mine. The thickness probably increases to the north and northeast.

The Zuloaga consists of thick-bedded (0.3 m to 2 m) light grey, lithologically homogeneous, fine-grained, monotonous limestone beds (Pl. 24, fig. 2) which are entirely devoid of macrofossils. The Zuloaga is deceptively similar to the Lower Cretaceous Taraises Formation which overlies the La Caja Formation and their distinction usually necessitates the determination of stratigraphic position below or above the La Caja Formation. From its stratigraphic position conformably, but locally with conglomerate, underneath the fossiliferous (Upper) Kimmeridgian-Tithonian La Caja Formation, the Zuloaga is usually considered to be of Upper Oxfordian age. Moreover, the assumed near-shore equivalent of the Zuloaga, *i.e.* the La Gloria Formation north of the Sierra Catorce, has yielded Upper Oxfordian fossils.

Microscopic examination (specimen from the exposure along the jeep road to El Compromiso mine) shows pure microcrystalline

calcite with a few straight veins of calcite and two indistinct cross sections of microfossils.

LA CAJA FORMATION

The formation was named by Imlay (1938, p. 1659) for 43 to 91 m thin-bedded limestones and marls. The type section is at Vereda del Quemado in the Sierra de la Caja, Zacatecas (cf. Burckhardt, 1930, fig. 14; Imlay, 1938, p. 1660).

The La Caja Formation, which conformably overlies the Zuloaga Limestone, has yielded all fossils under study and is of principal stratigraphic interest. The exposed thickness varies from a few metres to a maximum of 53 metres. The La Caja is composed mainly of interbedded limestones and marls with some beds of sandstone and shale; conglomerate may be present at the base (El Pastor) but beds of conglomerate are rare within the section. The limestones are somewhat granular, and generally grey to dirty yellowish in colour; commonly they are soft and friable although some harder beds also occur. Grading and lamination are absent. The limestones differ markedly from those of the Zuloaga Formation and of the Taraises Formation which are thick-bedded, fine-grained, hard, and uniformly grey in colour. The marls have varying shades of pink, grey, and yellow, are also soft and friable, and often laminated. The sandstones are coarse-grained, grey and soft, but devoid of grading or lamination. The shales occur in shades of yellow, red or grey; they are fine-grained, often laminated, and soft.

Although normally exposed near the mountain tops, the La Caja is sometimes well preserved in downfaulted inliers as in the outcrops of San Andrés, El Verde, Los Alamitos, and El Pastor. The formation can be recognized from a distance by its pinkish-light grey appearance and by being sandwiched between the limestones of the Zuloaga below, and the Cretaceous Taraises Formation above.

The examination of about 20 thin sections of La Caja limestones showed several varieties. Almost all limestones examined contain fine-grained calcite which is probably recrystallized. These limestones are distinctly different from the micrite of the Zuloaga Limestone. (i) The limestones of the Virgatosphinctinae beds of the lower member at El Pastor and Los Alamitos are composed of abundant shell fragments which appear either micritic or sparry.

The matrix is composed of recrystallized sparry calcite sometimes showing polysynthetic twinning. Quartz is rare. Limonite appears as small, opaque rounded grains or as recrystallized shell fragments; some hematite may also be present. (ii) Specimens of limestones from the middle portions of the La Caja Formation do not contain any large shell fragments but appear to have sparse microfossils. The specimens are mostly very fine-grained calcite; some larger grains are long and thin. There is an abundance of limonite and hematite, which appear as dark specks in transmitted light. In reflected light hematite is crimson red or steel grey and limonite light to dark brown. Microfossils have been replaced by limonite. Some of the dark grains may be clay minerals. Small grains of angular quartz are also present. Some specimens also have a few grains of plagioclase. (iii) The third variety occurs either near the base or near the top of the formation. The limestone is extremely fine-grained calcite with even texture; dark grains are rare or absent. There are virtually neither quartz nor shell fragments. Some irregular patches of sparry calcite may be present here and there. Some specimens have thin intersecting veins of calcite. (iv) Some limestones which appear as fine-grained pink in hand specimens are composed of fine-grained probably recrystallized calcite with a fair amount of clay minerals and fine grains of hematite. Lamination may be present. (v) Towards the very top of the formation, around Real de Catorce, occurs a limestone bed with pinkish wrinkled top surface. Study of several thin sections indicated that the top c. 35 mm of the bed is composed of vertical columns of sparry calcite with very small amounts of hematite cement. Hematite appears to be concentrated at the bottom of the columns of sparry calcite which is here relatively coarse. Accessories include limonite and clay minerals as well as minor amounts of plagioclase and a few quartz grains.

Only single slides of the marls and shales were examined. The shales are fine-grained, even textured, homogeneous, and composed of clay minerals. The specimen of marls contains fine-grained recrystallized calcite and a good proportion of clay minerals besides hematite and limonite.

The La Caja Formation of Sierra Catorce is here divided into the El Pastor Member dominated by thick limestone beds, below,

and the El Verde Member consisting of interbedded thin limestones and shales, above. The two members also differ in their ammonite assemblages.

El Pastor Member. — The stratotype is the locality 40 of this work, *i.e.* the lower 28 m of the section along the creek through El Pastor near the midwestern margin of Sierra Catorce (Text-fig. 7; Pl. 23, fig. 2; Pl. 24, figs., 1, 4).

The limestone beds are light to dark yellowish or grey, up to 3 m in thickness, relatively soft and in some sections highly fossiliferous. Interbedded with these limestones are thinly laminated, easily weathering pink and whitish grey shales. The best exposures are in the vicinity of Los Alamitos and El Pastor. At El Pastor, poorly preserved *Idoceras* spp. are common at a horizon approximately 3 m above the base. The only other fossiliferous beds are at the top of this member, *i.e.* the uppermost three meters of this section (Pl. 23, fig. 2). They are here called Virgatosphinctinae Beds on account of the abundant occurrence of *Aulacosphinctoides* (2 species; most common) *Subdichotomoceras* (1 species), *Virgatosphinctes* (3 species), and *Pseudoinvoluticeras* (1 species). There are also abundant *Andiceras* as well as common *Haploceras* (2 species) *Pseudolissoceras* (1 species) and rare *Aspidoceras* (3 species), *Phylloceras* (2 species), "*Paraglochiceras*" (?2 species), *Mazapilites* (1 species), *Physodoceras* (1 species), and *Simoceras* (1 species). Bivalves are also extremely abundant. At El Pastor, the fossils of the Virgatosphinctinae beds are imperfectly preserved, partly because of structural complications. At Los Alamitos, these beds are also packed with ammonites and bivalves with similar modest preservation. However, sufficient better preserved material can be obtained.

El Verde Member. — The stratotype is the locality 14 of this work, *i.e.* the upper 25 m of the section exposed immediately north of the village El Verde in the central part of Sierra Catorce (Pl. 23, fig. 1; Text-fig. 4).

The limestone beds are thinner (average 0.15 m, maximum 0.3 m) and somewhat harder than in the El Pastor Member. The shales are similar in lithology, except that several thin (c. 0.1 m) beds of dark red and ochre-yellow shale occur at irregular intervals. A peculiar structure which simulates mud cracks, composed of inter-

secting ridges of calcite, appears on the top pinkish or black surface of a few granular limestone beds in the uppermost part of the section. The beds showing these structures can be recognized as marker beds in almost all exposures of this member in Sierra Catorce. This member is also exposed in the vicinities of Real de Catorce, La Leona, Cieneguita, and Los Alamitos. The fossils are not concentrated in single beds as in the El Pastor Member but sporadically distributed requiring careful search. The lower 10 m has yielded *Corongoceras* (2 + ? 1 species), *Durangites* (7 + ? 1 species), *Micracanthoceras* (1 species), and *Kossmatia* (5 species); the upper 10 m, *Substeueroceras* (3 species + 1 subspecies) and *Berriasella* (5 species).

Where the El Verde Member has been exposed on flattish mountain tops, weathering has produced much talus and obscured the outcrop. Thus, the ammonites are most commonly found in the talus. It is then necessary to determine either stratigraphically or by finding *in situ* fossils, whether the particular exposure belongs to the upper or the lower part of the El Verde Member.

TARAISES FORMATION

This formation was named by Imlay (1936, p. 1111) for about 150 m thick-bedded limestones. This type section is in Cañon Taraises, Coahuila.

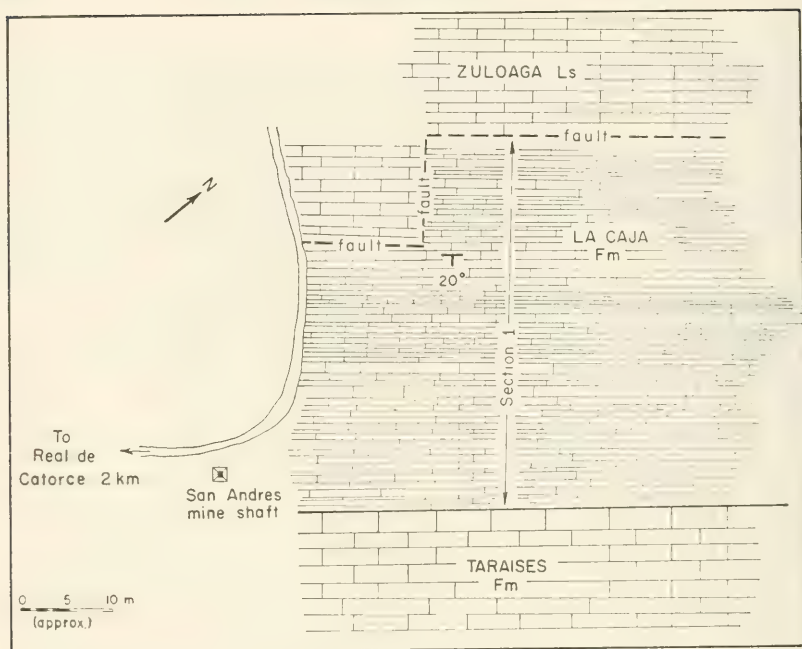
IMPORTANT SECTIONS OF THE LA CAJA FORMATION

Four fairly complete stratigraphic sections and a large number of outcrops of the La Caja Formation were sampled. The former are affected by structural disturbance, while the latter are partly obscured by talus.

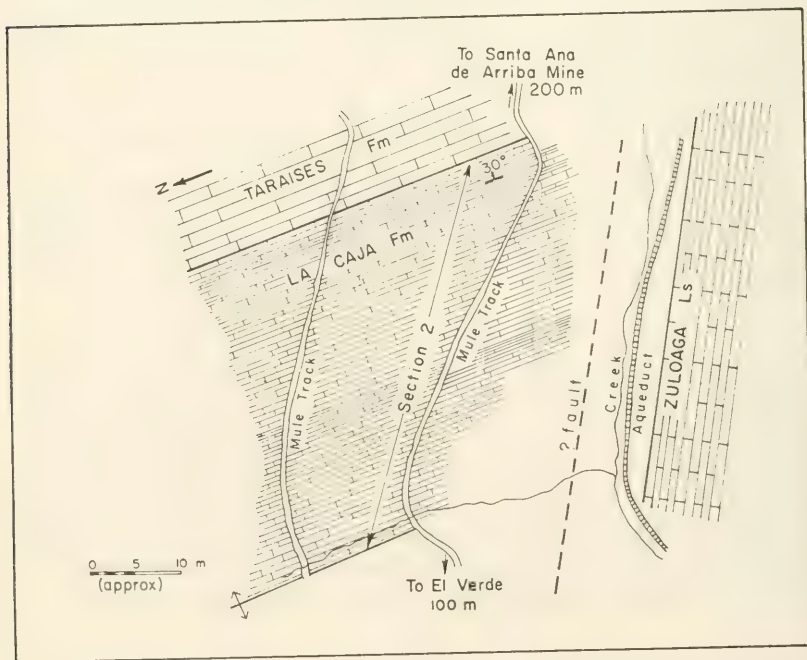
SAN ANDRÉS MINE SECTION

San Andrés silver mine, now abandoned, is located about 2 km northeast of Real de Catorce (Text-figs. 3,5). The entire block comprising the Zuloaga Limestone, the La Caja Formation, and the Taraises Formation has been downfaulted along two faults. A small fault cuts the La Caja-Zuloaga sequence vertically while a strike-slip fault on top of the Zuloaga Limestone has resulted in the local loss of the El Pastor Member.

The La Caja comprises the grey limestones and pinkish- to



Text-fig. 3. — Sketch map of the San Andrés section



Text-fig. 4. — Sketch map of the El Verde section, stratotype of the El Verde Member of the La Caja Formation (see Pl. 23, fig. 1).

whitish-grey shales. In the lower part, the limestones are thick-bedded; in the upper part, thin limestone beds alternate with shales and a few sandstone beds. In the middle of the sequence are a couple of beds of conglomerate composed of limestone pebbles. Although fossils occur in several beds, they are not common in this section and most specimens came from the talus. *In situ* collecting was hampered by the friability of the sandstones, especially in the lower part, and the fragility of the fossils embedded in them. However, some fossils were collected *in situ* and attempts made to determine the source beds of the others. In the following descriptions, *ex situ* fossils from inferred horizons are placed in brackets.

SECTION NO. 1

TARAISES FORMATION

Thick-bedded, hard, fine-grained limestones

LA CAJA FORMATION, EL VERDE MEMBER

- | | |
|--------|--|
| 16.2 m | Interbedded thin (c. 0.15 m) beds of friable grey limestones, shales and marls, with a few thin sandstone beds. Two limestone beds have pink top with ridges simulating mud cracks. At about 5 m from the top occur <i>Berriasella</i> cf. <i>B. picteti</i> , <i>B. lorioli</i> ?, and <i>B. aff. B. zacatecana</i> . |
| 4.5 m | Dark grey friable limestones with a few thin shale beds. Abundant <i>Kossmatia purissima</i> , n. sp., [<i>K. bifurcata</i>]. |
| 3.0 m | Interbedded red shales and grey limestones. |
| 1.0 m | Thick beds of limestone and shales, with [<i>Corongoceras mendozanum</i> , <i>C. cordobai</i> , n. sp.]. |
| 1.3 m | Grey limestones and shales with two thick beds of conglomerate, composed of limestone pebbles. |
| 1.0 m | Interbedded shales and marls. |
-

EL PASTOR MEMBER (?)

- | | |
|----------|---|
| 0.6 m | Thick limestone bed with <i>Subdichotomaceras</i> , n. sp. aff. <i>S. inversum</i> , abundant bivalves, brachiopods, and belemnites (= <i>Virgatosphinctinae</i> bed?). |
| c 12.0 m | Interbedded grey, friable, thick limestones and pink, grey or ochre-yellow shales and marls showing effects of structural disturbance. |

Total 39.6 m

— ? Strike-slip Fault —

ZULOAGA LIMESTONE

It appears that the Virgatosphinctinae beds of the El Pastor Member which are extremely fossiliferous in Los Alamos and El Pastor (see below), are here poorly fossiliferous.

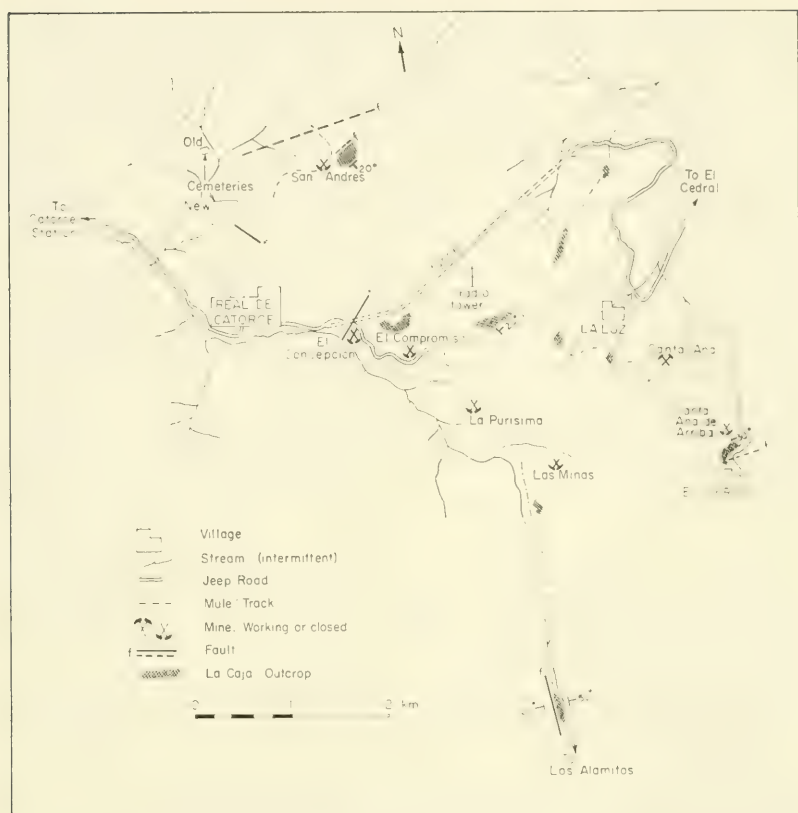
EL COMPROMISO MINE AND VICINITY

The El Compromiso mine (Text-fig. 5), now abandoned, is situated at the summit of a hill about 1.3 km east of Real de Catorce and is accessible by a jeep road. The hill consists almost entirely of Zuloaga limestones, with a thin capping of La Caja limestones, shales, and marls. Due northeast of the mine is a higher hill composed of thick-bedded limestones of the Taraies Formation. This hill is identified by a radio transmission antenna at its peak.

Although this is one of the few undisturbed sections in the area where the La Caja rests normally on the thick Zuloaga limestones, the La Caja exposure is in large part covered by talus, formed by weathering of the limestones and shales. The fossils mainly occur in this talus (Loc. 2). Because of the distinctive lithology and the exposure of the (upper) contact with the Taraies limestones, there is little doubt that the fossils belong to the El Verde Member. They include *Berriasella* cf. *B. picteti*, *B.* cf. *B. lorioli*?, *B.* aff. *B. zacatecana*, *Kossmatia bifurcata*, *K. flexicostata*, *K. purissima*, n. sp. and *Corongoceras cordobai*, n. sp.

The La Caja exposed in the vicinity of El Compromiso is lithologically the same as at San Andres mine with beds of grey limestone and pinkish, whitish, and grayish shales, and beds carrying small ridges on the top pink or grey surface in the upper part. A north-south trending, about 3 m thick porphyritic dyke cuts the La Caja and the underlying Zuloaga Limestone in the lower part of the hill.

Several other small isolated exposures of the La Caja (Text-fig. 5) occur on the southern (Loc. 3) and on the eastern slopes of the hill with radio tower (Loc. 4) where a mule track leads down to the tunnel entrance. Locality 3 is poorly fossiliferous but has yielded *Kossmatia alamosensis*, *K. flexicostata*, and *K. purissima*, n. sp. Loc. 4 yielded *Berriasella subprivasensis* and fragments of belemnites. In the basal part of this section are several sandstone beds with black concretions. A small outcrop about 500 m south-



Text-fig. 5. — Sketch map of the area north and east of Real de Catorce showing the outcrops of the La Caja Formation (based on an aerial photograph taken for an agricultural survey, 1960).

west of the tunnel entrance along the mule track (Loc. 10) yielded *Kossmatia bifurcata*, *K. exceptionalis*, *K. flexicostata*, and *K. purissima*, n. sp. Another small outcrop about 500 m southeast of the radio antenna (Loc. 11), along the old road from Santa Ana to Real de Catorce, yielded *Kossmatia bifurcata* and *K. purissima*, n. sp. Small outcrops of the La Caja can also be seen near the top of the eastern slope of the ridge running north-south separating Real de Catorce from La Luz, but these did not yield any determinable fossils. Below the La Caja, along the transverse steep valleys of the creeks running NE-SW from the hill toward La Luz, one can see the vast thickness of the Zuloaga Limestone which is also exposed on the west side of the high ridge between Real de Catorce and El Compromiso mine. A much thinner sequence of Taraises limestones lies on top of the La Caja with a conformable contact. A few specimens of *Olcostephanus* were collected from limestones.

EL VERDE SECTION

One of the best exposures and the stratotype of the El Verde Member is approximately 200 m south of the Santa Ana de Arriba mine, along the mule track leading to El Verde (Pl. 23, fig. 1). It is the least disturbed of all the sections of the member exposed in the vicinity of Real de Catorce. The Santa Ana de Arriba mine is different from the Santa Ana mine (presently in production) located at the base of the same hill.

The La Caja forms an anticline underlain by Zuloaga Limestone and overlain by the Taraises Formation. The major part of the section belongs to the El Verde Member (Text-fig. 4), while part of the El Pastor Member lies in the core of the anticline and is obscured by talus. Because the western limb of the anticline is poorly exposed, only the eastern limb was investigated. Across the valley, a thick succession of Zuloaga Limestone is visible, but the La Caja is absent there. The different attitude of the limestone strata across the valley suggests that a fault runs along the valley which has upthrusted the Zuloaga Limestone so that the La Caja was eroded from the top.

The eastern limb of the anticline is structurally only slightly disturbed. A transverse fault, traversing the section about 4 m above the mule track, has caused a displacement of about 3 m as is evident towards the top of the section (Pl. 23, fig. 1).

The El Verde section has the same lithology as the El Verde Member of other localities, *i.e.* friable grey limestones interbedded with pinkish, greyish, or whitish shales, and a few sandstone beds. Also present in the lower part of the section are several thin red- and ochre-yellow shale beds while the upper part contains two limestone beds with ridged pink top surface. The thickness of the section exposed here is about 35 m. The talus yielded fossils at two levels, approximately 10-20 m and 25-30 m from the base. The nature of the outcrop is such that the lower talus level may contain a small admixture from the upper level. The lower talus contained *Pseudolissoceras zitteli*, *Kossmatia bifurcata*, *K. purissima*, n. sp., *Substeuerocheras catorcense*, n. sp., *Corongoceras mendozanum*, and *C. cordobai*, n. sp.; the upper talus included *Substeuerocheras catorcense*, n. sp., *Kossmatia bifurcata*, *K. flexicostata*, *K. exceptionalis*, and *Berriasella subprivasensis*. *Pseudolissoceras* and *Corongoceras* are restricted to the lower talus and, therefore, not derived.

SECTION NO. 2

TARAISES FORMATION

(bed)

LA CAJA FORMATION, EL VERDE MEMBER

1.5 m	Interbedded hard grey limestones, marls, and sandy shales.
0.3 m (n)	Grey limestone bed capped by about 5 cm red-coloured sandstone.
1.3 m	Thinly (4-8 cm) interbedded marls and limestones with about 10 cm of ochre-yellow shale at the top. Sparsely fossiliferous.
0.15 m (m)	Hard, grey sandstone.
0.6 m	Marls, sparsely fossiliferous with indeterminable fossil fragments.
0.15 m (la)	Limestone with apparent large-scale ripple marks due to wavy folding of the whole bed.
1.3 m	Interbedded thin marls and limestones. <i>Substeuerocheras catorcense</i> .
0.15 (l)	Grey limestone with pink top surface showing ridges.
0.15 m	Pinkish-grey shale.
0.15 m (ka)	White calcitic bed showing slickensides, very distinctive.
4.0 m	Thin beds of shales and limestones with fossils showing on the top surface of the latter. <i>Kossmatia flexicostata</i> , <i>K. alamosensis</i> , <i>Substeuerocheras catorcense</i> , n. sp.

0.3 m (k)	Soft, light grey, granular limestone.
3.0 m	Pink shales and grey limestone beds (7-15 cm).
0.15 m (j)	Fine-grained grey limestone with black top surface simulating mud cracks.
1.0 m	Marls.
0.15 m (i)	Limestone bed with indeterminate fragments of fossils at the base.
0.3 m	Greyish-pink sandy shales and limestones.
0.15 m (h)	Thick limestone bed. <i>Kossmatia bifurcata</i> , <i>K. flexicostata</i> , <i>K. purissima</i> , n. sp., <i>Berriasella subprivasensis</i> , and fragments of belemnites.
1.3 m	Shales and limestones thin-bedded (5-10 cm) greyish brown shale bed at the base.
0.25 m (g)	Grey limestone.
1.3 m	Pinkish clays with about 6 cm limestone bed in the middle and about 3 cm ochre-yellow clay at 0.15 m below top.
0.3 m (f)	Grey limestone.
1.3 m (e)	Interbedded grey limestone and pink shales. Indeterminate fossil fragments at middle and 0.3 m from top.
0.6 m	Grey limestone, very friable.
0.3 m	Pinkish shales, marls and sandy shales.

EL PASTOR MEMBER

0.15 m (d)	Grey limestone, poorly fossiliferous. <i>Subdichotomoceras</i> , n. sp. aff. <i>S. inversum</i> .
0.15 m	Pink shale.
0.15 m (c)	Reddish-grey limestone.
2.6 m	Limestones and shales with 10-15 cm beds, shales predominating.
0.3 m (b)	Grey limestone.
1.3 m	Interbedded limestones and clays, clays predominating.
0.6 m (a)	Limestone, very friable. Abundant bivalves, brachiopods, and belemnites. 6-9 cm at the base, red and ochre-yellow clay.
0.15 m	Grey sandstone, very friable.
10.0 m	Whitish grey very friable calcareous muds and thin limestones.

Total 35.55 m (Axis of anticline)

There are two other small isolated outcrops in the vicinity of El Verde. Locality 15 is near the top of the hill slope approximately 1 km northeast of El Verde. The outcrop is obscured by talus which yielded *Berriasella lorioli*?, *B. subprivasensis*, *Kossmatia bifurcata*, *K. flexicostata*, *K. purissima*, n. sp., *Substeueroceras alticostatum*, *Corongoceras mendozanum*, and *C. cordobai*, n. sp. From the talus of Locality 16, the hill slope about 2 km northeast of El Verde, *Berriasella* aff. *B. zacatecana*, *Substeueroceras alticostatum*, *S. storrsi*, *Durangites heilprini*, *D.* aff. *D. heilprini*, and *D. vulgaris* were yielded.

LOS ALAMITOS SECTION

The village of Los Alamitos is situated in an east-west running valley approximately 10 km southeast of Real de Catorce. An excellent exposure of the El Pastor Member is along the hill slope just south of Los Alamitos (Pl. 22, fig. 2). In the vicinity are also two isolated exposures of the El Verde Member. Small outcrops of this member also lie in the area between Real de Catorce and Los Alamitos.

The structure between Real de Catorce and Los Alamitos consists of two anticlines and two synclines with north-south axis (Text-fig. 6). The axis of the first anticline is at the top of the valley running south-southeast from El Compromiso. Here the anticline is faulted and intruded by porphyry along the axis. The east limb dips 50°E, the west limb 20°W.

From a small isolated outcrop along the mule track just south of the La Purisima mine (Loc. 17) *Kossmatia exceptionalis* and *K. flexicostata* were recovered. Along the creek towards the head of the valley (Loc. 18.), about 5 m of the El Verde Member is exposed, followed by about 40 m of Taraises limestones. The talus yielded *Berriasella* cf. *B. picteti*, *Kossmatia alamosensis*, *K. bifurcata*, *Substeueroceras catorcense*, n. sp., *Durangites heilprini*, and *Micracanthoceras acanthellum*.

The Taraises limestones encountered south of this anticline are sparsely fossiliferous. Some of the ammonites appear in the form of sections on the fractured rock, while others are internal moulds and can be identified with *Olcostephanus* sp. These limestones invariably show yellow, oval, extremely hard, siliceous concretions in

the beds with their long axes parallel to bedding planes. The limestones also contain calcitic veins cutting the beds randomly and occasionally poorly developed stylolytic structures in the middle of a bed. The structures are rare in the Zuloaga limestones and hence can be used to tentatively distinguish between the two limestone formations which otherwise are much alike.

Along the mule track to Los Alamitos, respectively at 4 and 3 km northeast of the village, one encounters beneath the Taraises limestones two small outcrops of the El Verde Member which form the core of the second anticline. The lithology of these beds is the same as that of the upper beds of La Caja in the El Verde section. In the first outcrop (Loc. 19A), the pure white calcite bed equivalent to bed 'ka' of El Verde and the superjacent limestone bed with pink ridged top surface can be recognised. In this outcrop, the talus from the west limb of the anticline yielded *Berriasella subprivasensis*, *Kossmatia bifurcata*, *Substeuerocheras koeneni tabulatum*, n. subsp., *S. catorcense*, n. sp., *Durangites heilprini*, *D.* aff. *D. heilprini*, and *D. alencasteri*, n. sp., while the talus from the east limb of the anticline (Loc. 19D) contained *Berriasella subprivasensis*, *Kossmatia alamosensis*, and *Substeuerocheras catorcense*, n. sp. An isolated limestone bed (Loc. 19C) approximately about 10 m above bed 19A produced *Kossmatia bifurcata* and *Substeuerocheras koeneni tabulatum*, n. subsp. Talus from the second locality (Loc. 20) on the hill slope yielded from the west limb of the anticline (Loc. 20A) *Substeuerocheras catorcense*, n. sp. and *Durangites vulgaris*, and from the east limb (Loc. 20B) *S. catorcense*. Although most of the fossils from these exposures came from talus, the source beds belong almost certainly to the El Verde Member.

The second syncline with a north-south axis is encountered in the valley of Los Alamitos. South of the village, the steep and mostly barren slope exposes the La Caja Formation in the core of an isoclinal syncline, flanked on both sides by the (underlying) Zuloaga Limestone (Pl. 22, fig. 2). A shear zone and a fault are present just west of the synclinal axis and the west limb of the syncline is overturned. On the northern slopes of the valley appears to be an east-west fault offsetting the Zuloaga and the La Caja. The inferred axis of the syncline runs north-south on the southern slopes of the valley, but gradually changes to NNE-SSW on the

northern slopes; here the syncline becomes less tight, the flanks diverge and the core exposes the Taraises Formation.

The east limb of the syncline exposed on the hill slope south of the village (Pl. 22, fig. 2) is of particular paleontological interest because it is one of the two good sections in the Sierra Catorce with highly fossiliferous El Pastor Member. The ammonites, however, are concentrated in a small interval of about 0.6 m, the Virgatosphinctinae beds, approximately 14 m above the base. The ammonites, especially the larger ones, are of modest preservation and rarely complete.

SECTION NO. 3

(Axis of syncline)

4.0 (?) TARAISES FORMATION: Limestone beds, highly sheared, fine grained, hard.

LA CAJA FORMATION, EL VERDE MEMBER:

10.0 m	(Covered by talus).
3.0 m	Grey limestone, pink shales, and marls in 10-20 cm thick beds.
3.0 m	Hard, fine-grained, grey limestone.
4.0	Interbedded limestones and marls in 10-20 cm beds.
0.15 m	Shales and marls.
0.3 m	Pink shales and limestones.
0.15 m	Hard, grey limestone.
1.5 m	Pink shales, marls, and limestones.
0.3 m	Hard, grey limestone with pink top surface with ridges.
1.2 m	Pink shales and thin-bedded limestones.
0.2 m	Grey limestone with fragmentary fossils.
3.0 m	Interbedded limestones and marls.
0.2 m	Fine-grained, hard grey limestone.
2.0 m	Interbedded pink and grey marls.
0.15 m	Grey limestone with indeterminate fossil impressions.
0.6 m	Grey marls.
0.3 m	Grey limestone.
0.6 m	Greyish and yellow marls.
0.6 m	Hard limestone with a few indeterminable ammonite impressions.

EL PASTOR MEMBER

- 0.6 m Virgatosphinctinae bed: Massive, hard, grey-yellow limestone forming a ridge. Several hundred ammonite specimens collected *in situ*, while talus on the outcrop yielded essentially the same fauna. *Phylloceras* cf. *P. subplicatus*, *Phylloceras* sp. juv.?, *Haploceras transatlanticum*?, *Pseudolissoceras zitteli*, cf. "*Paraglochiceras*" sp. indet., *Mazapilites mexicanus*, *Aulocosphinctoides lauri*, *Subdichotomoceras*, n. sp. aff. *S. inversum*, *Virgatoshinctes sanchezi*, n. sp., *Aspidoceras alamitocense*, *A.* cf. *Alamitocense*, *A. haupti*, *A.* cf. *A. haupti*, *Andiceras lenki* and *A. monserrati*. Abundant bivalves, brachiopods, a few gastropods, belemnites, and aptychi.
- 14.0 m Weathered yellow-grey limestone, homogeneous, same as before but more friable.

Total 49.85 m

ZULOAGA LIMESTONE

The El Verde Member is poorly fossiliferous in this section but yielded abundant fossils in two exposures on the northern slopes of the valley of Los Alamitos. One is located on a hill slope just north-east of the village (Loc. 22) and contains, above, *Berriasella* cf. *B. picteti*, *B.* aff. *B. zacatecana*, *Kossmatia bifurcata*, *K. exceptionalis*, *Substeuerocheras alticostatum*, *S. catorcense* n. sp. and, somewhat lower, *Corongoceras*? n. sp. indet, *Durangites heilprini*, *D. vulgaris*, *D.* n. sp. aff. *rarifurcatus*, *D. alencasteri*, n. sp., and *Micracanthoceras acanthellum*. The second exposure is at the head of a tributary valley, north of the village (Loc. 21) at the mule track from Real de Catorce into the Los Alamitos valley. From the talus of this exposure were recovered *Kossmatia exceptionalis*, *Substeuerocheras catorcense*, n. sp., and *Corongoceras*? n. sp. indet.

LA LEONA

The mule track to the village La Leona (Text-fig. 6) descends along the strike of the El Verde Member consisting of pink shales and thin hard grey limestones which are sparsely fossiliferous and dip 30-40° east. These beds form part of the east limb of the faulted and intruded anticline exposed at the head of the valley south-south-east of the El Compromiso mine. A large outcrop of the El Verde Member further downhill has suffered structural disturbance. Near the village, the beds are down-faulted by an east-west fault and appear just north of the village. The last exposure of the El Verde Member is on the steep eastern slopes of the valley north of La

Leona (Loc. 25). Due to partial structural disturbance, it was not considered appropriate to measure and collect from the entire section. From the undisturbed part at about 10-15 m below the contact with the Taraises Formation, were collected *Aspidoceras* cf. *A. andinum*, *Berriasella* cf. *B. picteti*, *B. subprivasensis*, *B. aff. B. zacatecana*, *Kossmatia bifurcata*, *K. exceptionalis*, *K. flexicostata*, *K. purissima*, n. sp., *Substeueroceras alticostatum*, *S. catorcense*, n. sp., *S. storrsi*, *Corongoceras cordobai*, n. sp., and *Durangites heilprini*.

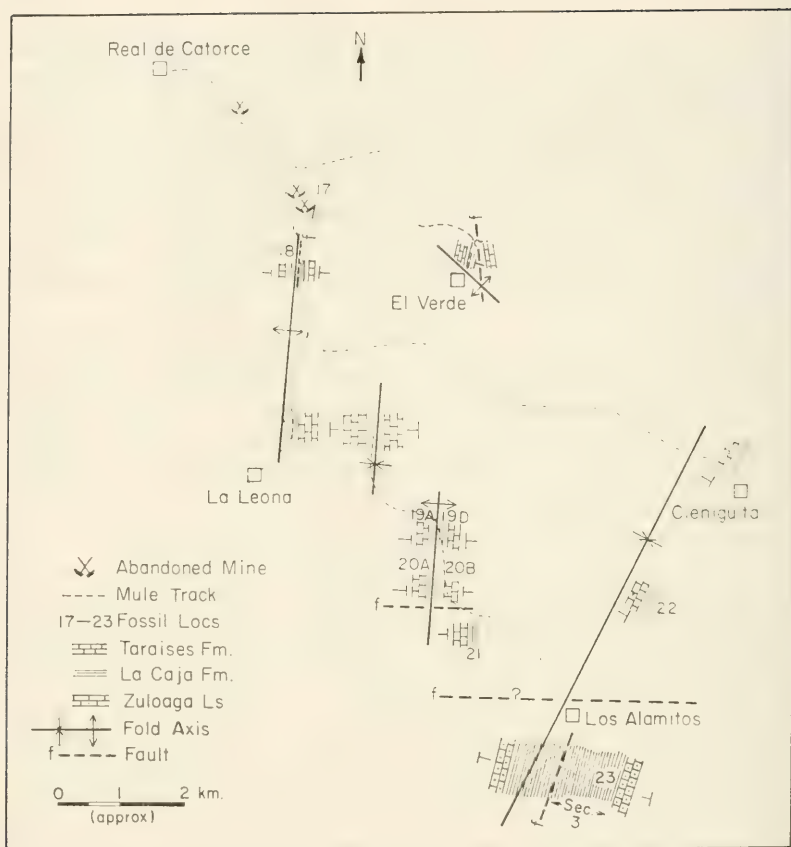
From the valley floor at a stream-cutting just south of the village (Loc. 27) came a few brachiopods and bivalves from beds which lithologically resemble the Virgatosphinctinae beds of Los Alamitos. Other obscure and sparsely fossiliferous outcrops include one just southeast of the village (Loc. 28) and talus 50 m higher on the same hill slope (Loc. 29).

CIENEGUITA

The village Cieneguita lies in the valley about 4 km northeast of Los Alamitos and the approach from Real de Catorce is by the same mule track that leads to Los Alamitos and to La Leona (Text-fig. 6). A few isolated small outcrops occur near this village. All of them belong to the El Verde Member as judged by the stratigraphic proximity to the Taraises Formation. From the talus about 2 km northwest of the village (Loc. 31) came *Substeueroceras koeneni tabulatum*, n. subsp., *S. catorcense*, n. sp., and *Durangites heilprini*, and *D. alencasteri*, n. sp. Another small outcrop just northeast of the village (Loc. 32) yielded in the upper 10 m, *Berriasella subprivasensis*, *B. aff. zacatecana*, *Kossmatia bifurcata*, *K. purissima*, n. sp., *Substeueroceras alticostatum*, *S. koeneni tabulatum*, n. subsp., *S. catorcense*, n. sp., and *S. storrsi*; in the lower 5 m, *Corongoceras?* n. sp. indet., *Durangites heilprini*, *D. vulgaris*, *D.* n. sp. aff. *D. rarifurcatus*, *D. alencasteri*, n. sp., and *Durangites?* n. sp. indet. Talus on the southwestern slope of the valley north of the village contained *Berriasella subprivasensis*, *Kossmatia bifurcata*, and *Substeueroceras alticostatum*.

EL PASTOR SECTION

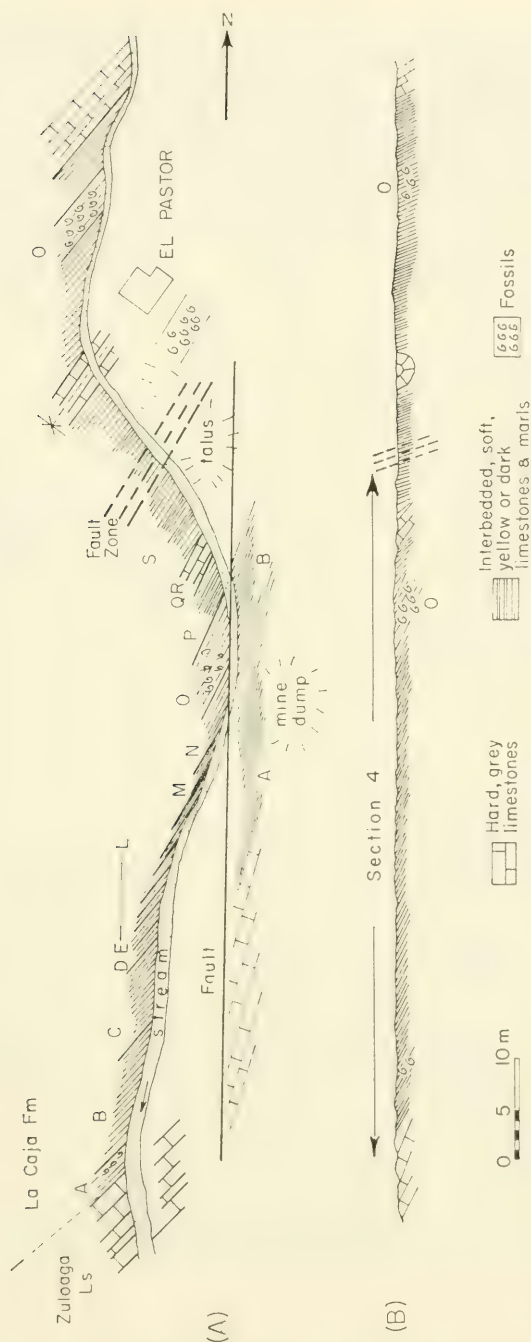
This important stratotype of the El Pastor Member is located in a creek which passes through the small village of El Pastor; it is



Text-fig. 6. — Sketch map of the area between Real de Catorce and Los Alamitos showing the outcrops of the La Caja Formation, fossil localities, and the inferred structure.

the most southerly locality studied in the Sierra Catorce (Text-fig. 7). Just west of El Pastor lies the village of Tierra Negras, noted for its working mercury mine.

The creek section through El Pastor is structurally complicated by two faults and a tight synclinal fold (Text-fig. 7). One major fault runs N-S along the creek and has almost cut off the exposures of La Caja Formation on the eastern bank; the other fault is a strike-slip zone about 10 m broad, approximately 35 m above the base of the La Caja resulting in the loss of a large part of the El Verde. These beds dip 25° - 30° N-NW. Above the fault zone, the synclinal fold has resulted in the repetition of some of the El Verde Member. The dips in the faulted and folded part of the section are as high as 70° , sometimes vertical.



Text-fig. 7. — The El Pastor section of the La Caja Formation showing the stratigraphy and structure of the El Pastor Member (stratotype). A. Plan of the outcrop. B. Vertical section along the west bank of the stream (see Pl. 23, fig. 2; Pl. 24, fig. 4).

SECTION NO. 4

TARAISES FORMATION: thick limestone beds with cherty concretions

	LA CAJA FORMATION
3.0 m	Virgatosphinctinae beds: yellow marls and limestones. Highly fossiliferous, same as (o).
8.0 m	Red and dark variegated shales and limestones, overturned.
3.0 m	Two thick limestone beds (forming a small synclinal fold).
3.0 m	Virgatosphinctinae beds: yellow marls and limestone, same as (o).
8.0 m	Shales and limestone, same as (s) below (probably repeated) due to fault).
(c. 10m)	 fault zone.....
6.0 m (s)	Dark reddish shales and limestones.
2.0 m (qr)	Shales with two 0.3 m limestone beds.
1.0 m (p)	Black limestone.

EL PASTOR MEMBER (STRATOTYPE)

3.0 m (o)	Virgatosphinctinae beds: yellow limestone packed with fossils (Pl. 23, fig. 2). (This bed is repeated approximately 17 m above on the east bank by faulting and, again about 30 m upstream beyond the synclinal fold). The fossils include <i>Phylloceras</i> cf. <i>P. subplicatus</i> , <i>Aulacosphinctoides lauri</i> , <i>Subdichotomoceras</i> , n. sp. aff. <i>S. inversum</i> , ? <i>Virgatosphinctes fresnosensis</i> , <i>V. sanchezi</i> , n. sp., <i>V.</i> aff. <i>V. communis</i> , <i>Simoceras</i> cf. <i>S. volanense</i> , <i>Andiceras monserati</i> , <i>A. lenki</i> , and many bivalves, brachiopods, belemnites, aptychi, and few gastropods.
2.0 m (n)	Black limestones, same as (1).
0.6 m (m)	Soft, friable, yellow marls.
2.0 m (1)	Black massive limestones, with sharp colour contact with (m)
0.3 m (k)	Grey massive limestones, weathering brown, with a few shale beds.
1.3 m (j)	Black limestone with marls.
2.0 m (hi)	Grey yellow massive limestone grading into black limestones above.
0.6 m (g)	Limestone.
0.3 m (f)	Grey limestone, weathering brown, similar to (d).
1.0 m (e)	Yellowish-grey limestone with marls.
0.3 m (d)	Grey limestone, weathering brown.
4.0 m (c)	Dark grey to yellow massive limestones.
5.0 m (b)	Hard limestones, calcareous sandstones, and shaley beds, 0.3 to 0.6 m thick; limestone beds predominating in the upper part; b/c contact bed is 0.3 m yellow weathering grey limestone.
5.0 m (a)	Dark grey limestones, shales, and yellow weathering marls with limestone pebbles and concretions, probably derived from the Zuloaga limestones (below). At 3 m from the base, <i>Idoceras</i> cf. <i>I. inflatum</i> , <i>I.</i> cf. <i>I. mutabile</i> , <i>I.</i> ex. gr. <i>I. neohispanicum</i> .

Total 36.40 m (below fault zone)

ZULOAGA LIMESTONE

In the vicinity of Tierras Negras are other small isolated exposures which are mostly obscured by talus and yielded indeter-

minable fragments of fossils. Talus in a field southeast of Tierras Negras contained some fragments of *Kossmatia* sp. Talus on a hill slope east of the village Jesus Pokito, about 1 km north of Tierras Negras, yielded *Olcostephanus* sp. A few impressions of indeterminate ammonites were recovered from talus on a hill slope near El Alamarito, about 2 km south of Tierras Negras.

TABLE 1. — FOSSIL LOCALITIES IN THE SIERRA CATORCE (SEE TEXT-FIG. 9, p. 152)

Locality No.	Catalogue No. (McM-J)	
1A	1494	<i>San Andrés section.</i> — Outcrop on northwest slope above San Andrés mine, approximately 2 km northeast of Real de Catorce. Mostly El Verde Member, El Pastor Member incomplete.
1B	1494A	Grey friable sandstone bed, approximately 19 m from base of section of loc. 1A. El Pastor Member, sparsely fossiliferous (equivalent to Virgatosphinctinae beds).
2	1495	Slope just northeast of El Compromiso mine, approximately 1 km east of Real de Catorce. Talus of limestone and marls of El Verde Member.
3	1522	Slope just south of radio antenna, approximately 2 km east of Real de Catorce. Same formation as loc. 2.
4	1537	Isolated exposure of soft sandstone bed along mule track on eastern slope of hill with radio antenna. Same formation as loc. 3.
5	1499	Small outcrop on south side of abandoned rail track running east from Santa Ana mine. Whitish-grey limestone and shales of Taraises Formation with <i>Olcostephanus</i> and indeterminate fossil fragments.
6	1496	Outcrop near top of high hill south of village La Luz, just northwest of Santa Ana mine. Limestone and shale of El Verde Member, with indeterminate fossil fragments.
7	1498	Road cut just north of village La Luz along jeep road from Santa Ana mine to Real de Catorce. Partly talus, same as loc. 6.
8	1497	Road cut about 150 m northeast of tunnel entrance on jeep road from Santa Ana mine to Real de Catorce. Whitish-grey shales and limestones with fragments of <i>Olcostephanus</i> sp.
9	1500	Small outcrop approximately 300 m south-southeast of tunnel entrance along old road leading over the mountain to Real de Catorce. Grey limestone of Taraises Formation with indeterminate fossil fragments.
10	1501	Small outcrop about 500 m southwest of tunnel entrance along old mule track leading from tunnel entrance over the mountain to Real de Catorce. Grey limestones and pinkish to yellowish marls of El Verde Member.
11	1523	Small outcrop approximately 500 m southeast of radio antenna along old road from Santa Ana mine to Real de Catorce. Same as loc. 10.

- 12 1524 Small outcrop near top of hill southwest of village La Luz, along old road from Santa Ana mine to Real de Catorce, at sharp bend to north. Grey limestones of Taraises Formation, with *Olcostephanus* sp. and indeterminable other fossils.
- 13 1525 Small outcrop just west of abandoned Santa Ana de Arriba mine, along mule track leading to village El Verde. Grey friable limestones, marls, and shales of El Verde Member.
- 14 1527 *El Verde section*.—Large outcrop about 100 m south of Santa Ana de Arriba mine, along mule track to village El Verde. Mainly El Verde Member (Stratotype).
- 14A 1526 Fossiliferous talus, 10-20 m above base of El Verde section.
- 14B 1526A Sandstone bed 'd', c. 15.5 m from base of El Verde section. El Pastor Member.
- 14C 1527 Fossiliferous talus at 25-35 m from base of El Verde section. El Verde Member.
- 14D 1527A Fossiliferous limestone bed 'h', c. 21.0 m from base of El Verde section. El Verde Member.
- 14E 1527B Sparsely fossiliferous limestone bed 'i' c. 21.4 m from base of El Verde section. El Verde Member.
- 14F 1527C Sparsely fossiliferous horizon, c. 26.6 m from base of El Verde section (c. 3.3 m below bed 'ka'). El Verde Member.
- 14G 1527D Fossiliferous limestone bed, c. 29.0 m from base of El Verde section (1 m below bed 'ka'). El Verde Member.
- 14H 1527E Sparsely fossiliferous horizon, c. 29.3 m from base of El Verde section (0.6 m below bed 'ka'). El Verde Member.
- 14I 1527F Sparsely fossiliferous horizon, c. 30.4 m from base of El Verde section (0.9 m above bed 'l'). El Verde Member.
- 14J 1527G Sparsely fossiliferous horizon, c. 31.2 m from base of El Verde section (0.6 m below bed 'la'). El Verde Member.
- 14K 1527H Fossiliferous limestone bed, c. 32.25 m above base of El Verde section (0.3 m above bed 'la'). El Verde Member.
- 14L 1527I Sparsely fossiliferous horizon, c. 32.2 m from base of El Verde section (0.6 m above bed 'la'). El Verde Member.
- 14M 1527J Sparsely fossiliferous horizon, c. 32.8 m from base of El Verde section (0.3 m above bed 'm'). El Verde Member.
- 14N 1527K *Ex situ* fossils from the entire El Verde outcrop.
- 15 1535 Near top of hill slope, approximately 1 km northeast of village El Verde. Talus from grey friable limestones and pinkish to yellowish marls of the El Verde Member.
- 16 1536 Hill slope approximately 2 km northeast of El Verde. Talus, same as loc. 15.
- 17 1502 Small outcrop along mule track just south of La Purisima mine. Same as loc. 15.
- 18 1503 Small outcrop at head of valley approximately 1 km south of Las Minas mine, uphill from La Purisima mine. Same as loc. 15.
- 19A 1515 Hill slope on west limb of anticline, approximately 4 km northwest of Los Alamitos, along mule track from Real de Catorce. Same as loc. 15.
- 19B 1515A Isolated limestone bed at loc. 19A. Sparsely fossiliferous, El Verde Member.
- 19C 1515B Isolated sandstone bed at loc. 19A, approximately 10 m stratigraphically above 19B. El Verde Member.
- 19D 1515C Hill slope along mule track on east limb of anticline, close to loc. 19A. Talus from El Verde Member.
- 20A 1538 Hill slope on west limb of anticline, approximately 3 km northwest of Los Alamitos. Talus from grey friable limestones and pinkish to yellowish marls of El Verde Member.

- 20B 1538A Hill slope on east limb of anticline, close to loc. 20A. Same as loc. 20A.
- 21 1504 Hill slope at head of valley just north of village Los Alamos where the mule track from Real de Catorce starts to descend into the valley. Same as loc. 20.
- 22 1508 Outcrop on hill slope just northeast of Village Los Alamos. Lower part of El Verde Member.
- 23A-C 1505-1507 *Los Alamos section*.—La Caja Formation.
- 23A 1505 Steep slope of hill just south of village Los Alamos. Greyish yellow limestones and marls, mostly El Pastor Member, talus.
- 23B 1506 Limestone bed, highly fossiliferous, 14 m above base of section of loc. 23A. Upper El Pastor Member, *Virgatosphinctinae* beds.
- 23C 1507 Sparsely fossiliferous beds 10-15 m above base of section of loc. 23A. Thin-interbedded hard grey limestones, shales and marls, lower part of El Verde Member.
- 24 1509 Area of Los Alamos, stream beds and talus from outcrops south of the village (? loc. 23B), collected by villagers.
- 25 1517 Outcrop on steep hill slope just north of village La Leona. Grey limestones, pinkish to yellowish shales and marls of El Verde Member.
- 26 1518 Stream cutting just south of village La Leona. Sparsely fossiliferous upper part of El Pastor Member.
- 27 1519 Stream cutting southeast of village La Leona. Same as loc. 26.
- 28 1520 Small outcrop just south-southeast of village La Leona, about 50 m south of loc. 40. Upper part of El Pastor Member.
- 29 1521 Hill slope about 50 m uphill from loc. 28. Sparsely fossiliferous talus from hard grey limestones of Taraises Formation.
- 30 1516 Streams near village La Leona, *ex situ* collection made by the villagers from La Caja Formation.
- 31 1510 Mule track about 2 km northwest of village Cieneguita, in valley about 4 km northeast of village Los Alamos. Talus from grey limestones and marls of El Verde Member.
- 32 1511 Small outcrop on hill slope just northwest of village Cieneguita. Same as loc. 31.
- 33 1512 Small outcrop on hill slope just northwest of village Cieneguita, about 100 m uphill of loc. 32. El Verde Member, sparsely fossiliferous.
- 34 1513 Southwestern slope of valley north of village Cieneguita. Talus of El Verde Member.
- 35 1514 Cieneguita area, *ex situ* collection made by villagers from El Pastor Member.
- 36 1534 San José de Coronados, approximately 5 km west of Tierras Negras at the foot of the Sierra Catorce. *Ex situ* collection of villagers from La Caja and Taraises Formations.
- 37 1533 Field southeast of Tierras Negras, on way to El Pastor. Talus from El Verde Member.
- 38 1532 Hill slope east of village Jesus Pokito, 1 km north of Tierras Negras. Talus from hard grey limestones of Taraises Formation.

- | | | |
|-------|-----------|---|
| 39 | 1531 | El Alamarito area, about 2 km south of Tierras Negras, <i>ex situ</i> collection of villagers from El Pastor Member. |
| 40A-F | 1528-1530 | <i>El Pastor</i> section.—Stream cut running through village El Pastor, about 500 m east of Tierras Negras (Stratotype of El Pastor Member, La Caja Formation). |
| 40A | 1530 | 3 m above base of El Pastor section. Yellowish friable limestones of the basal part of El Pastor Member. |
| 40B | 1530B | Sparsely fossiliferous horizon c. 3.3 m below bed 'o' of El Pastor section. El Pastor Member. |
| 40C | 1528 | Highly fossiliferous limestone beds (Virgatosphinctinae beds 'o'), 27.5 m above base of El Pastor section. Upper part of El Pastor Member. |
| 40D | 1530C | Sparsely fossiliferous limestone bed 'p' above bed 'o' of the El Pastor section. El Pastor Member. |
| 40E | 1529 | Same bed as 40C but on the east bank of the stream; c. 50 m upstream from 40C as a result of faulting. Same as 40C. |
| 40F | 1530 | Same bed as above repeated on the west bank north of the village due to synclinal folding. Same as 40C. |

ANALYSIS OF THE JURASSIC AMMONITE FAUNA OF SIERRA CATORCE

The fauna described here comprises 52 species belonging to 20 genera and 6 families of Ammonoidea. The distribution of genera among the families is: Phylloceratidae, 1; Haploceratidae, 3; Opheliidae, 1; Perisphinctidae, 5; Aspidoceratidae, 3; and Berriasellidae, 7 (including *Kossmatia*). Note the paucity of Phylloceratina and the absence of Lytoceratina among our material; one or two probable *Lytoceras* specimens were, however, described by Aguilera (*in* Castillo and Aguilera, 1895). The material included all specimens still available from the Castillo and Aguilera collection (Table 2) in Mexico and our large collections.

SAMPLE SIZE

The collections made by Verma consisted of about 4,000 specimens and fragments in various states of preservation stemming from 40 localities in the northern part of Sierra Catorce. A large proportion came from the thin interval named the Virgatosphinctinae beds of El Pastor and Los Alamitos which are packed with imperfectly preserved fossils. Time and transportation often were the only limitations on sample size. Almost one-half the total number of the specimens collected consisted of brachiopods and bivalves (handed over for study to Dra. Gloria Alencáster of the Instituto de Geología, Universidad Nacional Autónoma de México). Of the

slightly more than 2,000 ammonite specimens, only 637 relatively well-preserved and prepared specimens are recorded under "material" here, although the descriptions are based upon almost the entire ammonite fauna.

Table 3 (p. 148) gives the relative abundances and locations of the ammonite species described here. Thirteen species are identified only in single specimens: *Haploceras* cf. *H. elimatum*, "*Paraglochiceras*" *catorcense*, *Idoceras* cf. *I. inflatum*, *Pseudoinvoluticeras* cf. *P. mozambicum*, ? *Virgatisphinctes fresnosensis*, *V.* aff. *V. communis*, *Aspidoceras* cf. *A. alamtocense*, *A.* cf. *A. andinum*, *A. haupti*, *Physodoceras* (subgen. nov.?) *burkarti*, *Simoceras* cf. *S. volanense*, *Durangites acanthicus*, and *Durangites* ? n. sp. indet. The samples of the other species vary between two and several dozen well-preserved specimens.

PRESERVATION AND PREPARATION

Almost all the ammonite fossils occur in the form of internal molds of phragmocones, with the rare exception of test and body chamber preservation. Most specimens have suffered effects of diagenetic compaction, and invariably one side is better preserved than the other which has been either crushed or infilled with matrix. The body chamber being more fragile than the septate phragmocone, was crushed and destroyed. The better preservation of one side suggests that during horizontal burial, the shell was punctured and filled with "draught fill" sediment ("case 6" of Seilacher, 1971, p. 19). All the fossils are calcified, with calcite crystals commonly present in the camerae. Silicification has not been observed. Some specimens, especially in the El Verde Member of the La Caja Formation have attached oysters or serpulids, particularly in the umbilicus. The serpulids occasionally appear to grow along the umbilical seam and might have been true epizoans. The specimens of the Virgatosphinctinae beds give the appearance of having been reworked and the assemblage of this horizon may, therefore, be "condensed".

Generally the internal molds from the El Verde Member of the La Caja Formation differ in preservation from those of the El Pastor Member in the somewhat darker grey colour and greater hardness. The matrix can be loosened by impregnation with 2-3% acetic or hydrochloric acid. Rough mechanical removal of matrix can

then be carried out with pneumatic hammer, followed by the use of either a vibrotool under the microscope or an airbrasive. In the final stages of preparation great care is needed so as not to damage the ribs or the tubercles present in many species.

The fossils of the El Pastor Member of the La Caja occur as recrystallized internal molds with test more frequently preserved than in the El Pastor Member. Fossils as well as matrix consist of hard, yellowish granular calcium carbonate and the two are sometimes difficult to distinguish. Impregnation with weak acid as above directly followed by the use of a vibrotool under the microscope has proved to be the best technique of preparation.

DOUBTFUL DETERMINATIONS

Of the 52 species described here 31 are identified and 10 compared with previously known species; 5 are new (named) and 4 possibly new (not named). One subspecies is also new.

Phylloceras juv. ? indet. is represented by 14 small specimens with the septal sutures missing typical phylloid endings and somewhat resembling *Calliphylloceras*; ornament and constrictions are obsolete. *Haploceras transatlanticum* Burckhardt? comprises 11 small imperfectly preserved specimens. The four ill-preserved specimens of cf. "*Paraglochiceras*" sp. indet. apparently lack a lateral groove, have whorls more inflated than *Hildoglochiceras* and show clearly the falcoid ribs on the outer flanks. The doubtful *Virgatosphinctes fresnosensis* Imlay is based on one fragment of a large phragmocone whorl. The five-whorled fragments tentatively placed in *Berriasella lorioli* (Zittel) are too incomplete for a precise specific determination. In the four moderately preserved incomplete specimens of *Corongoceras*, n. sp. indet., the lateral tubercles are evident only as faint swellings. Nevertheless the circular whorl section is characteristic of *Corongoceras* as are the thick clavate ventrolateral tubercles. Finally, a single good specimen with distinct sporadic ventrolateral tubercles on the early part of the outer whorl is tentatively assigned to an unnamed new species of *Durangites*; it differs from known species in the fasciculate ribbing resembling *Virgatosphinctes* and the coarse primaries and involute coiling reminiscent of *Nothostephanus*.

SEXUAL DIMORPHISM

Thirteen species occur in probably dimorphic pairs, *i.e.* *Pseudolissoceras zitteli* (Burckhardt), *Aulacosphinctoides lauri* (Aguilera), *Subdichotomoceras*, n. sp. aff. *S. inversum* Spath, *Virgatosphinctes sanchezi*, n. sp., *Kossmatia alamitosensis* (Aguilera), *K. bifurcata* (Aguilera), *K. exceptionalis* (Aguilera), *K. flexicostata* (Aguilera), *Substeueroceras catorcense*, n. sp., *S. koeneni tabulatum*, n. subsp., *Andiceras monserati* (Aguilera), *Corongoceras cordobai*, n. sp., and *Durangites alencasteri*, n. sp. Significantly this includes most of the relatively abundant and, therefore, better known species. Notable exceptions are the genus *Berriasella* and *Andiceras lenki* (Aguilera) (Table 2). However, preservation is generally incomplete without aperture and usually even without body chamber. The criteria used for dimorphism include co-occurrence, identity of the inner whorls, and adulthood of the microconchs as indicated by egression of the body chamber from impressions on the penultimate whorl and septal approximation. In a few cases apertural modifications of ornament can be seen. The relatively rare species are only known in either macro- (♀) or microconch (♂), *e.g.* *Durangites acanthicus* Burckhardt (? ♂) and *D. vulgaris* Burckhardt (♀). It is noted that lappets are now known from *Durangites astillerensis* Imlay (1939) from Coahuila.

TAXONOMIC REVISION

Genus-group Level.—The classification at the genus-group level is in accordance with the Treatise on Invertebrate Paleontology (Arkell, *et al.*, 1957), with the following exceptions:

Kossmatia Uhlig is transferred from the Ataxioceratidae to the Berriasellidae. *Parodontoceras* Spath is placed in synonymy with *Substeueroceras* Spath. *Micracanthoceras* Spath is tentatively classified as a genus, not as a subgenus of *Himalayites* Uhlig; alternatively it could be considered as a subgenus of *Durangites*.

The reasons for the above changes are given in the discussions of the respective genera in the systematic descriptions.

Species-group Level.—The following taxonomic revisions of Aguilera's Jurassic ammonite species (*in* Castillo and Aguilera, 1895) includes information on the type specimens. The majority of the types are repositied at Instituto de Geología, Universidad Nacional

Autónoma de México, México, D. F. [UNAM]; several types are available only as plaster casts (plastotypes) at the U.S. National Museum, Washington, D.C. [P-USNM]; while several types are missing [-]. Presence or absence of new material from Sierra Catorce is also indicated.

TABLE 2. REVISION OF AMMONITE SPECIES PREVIOUSLY NAMED FROM SIERRA CATORCE

Aguilera (1895)	Material		Revision (with author or here)
	Types	New	
<i>Perisphinctes</i> cf. <i>balderus</i> Oppel	—	—	<i>Idoceras</i> cf. <i>balderus</i> (Oppel) — Burckhardt, 1930.
<i>Perisphinctes lenki</i> , n. sp.	UNAM	—	<i>Andiceras lenki</i> (Aguilera) — here; Burckhardt, 1930, and Imlay, 1939 to <i>Kossmatia</i> .
<i>Perisphinctes flexicostatus</i> , n. sp.	UNAM	+	<i>Kossmatia flexicostata</i> (Aguilera) ♀ — Burckhardt, 1930 to <i>Kossmatia</i> .
<i>Perisphinctes alamosensis</i> , n. sp.	UNAM	+	<i>Kossmatia alamosensis</i> (Aguilera) ♀ — Burckhardt, 1930.
<i>Hoplites calisto</i> var. (d'Orb.) (Pl. XI, fig. 2)	—	+	? <i>Substeueroceras storrsi</i> (Stanton) — here; Stanton, 1895 to <i>Hoplites storrsi</i> ; Burckhardt, 1930 to <i>Berriasella</i> cf. <i>storrsi</i> .
(Pl. XXII, fig. 2)	—	+	<i>Kossmatia</i> sp. — here; Burckhardt, 1930 to <i>Kossmatia potosina</i> (nom. nud.).
<i>Rhacophyllites</i> ? <i>alamosensis</i> , n. sp.	UNAM	+	<i>Kossmatia exceptionalis</i> (Aguilera) ♀ — here [<i>non Perisphinctes alamosensis</i>]; Burckhardt, 1930 to <i>Steueroceras</i> ; Imlay, 1939 to <i>Substeueroceras</i> .
<i>Hoplites exceptionalis</i> , n. sp.	UNAM	+	<i>Kossmatia exceptionalis</i> (Aguilera) ♀ — here; Burckhardt, 1930 to <i>Steueroceras</i> ; Imlay, 1939 to <i>Substeueroceras</i> .
<i>Rhacophyllites</i> ? <i>disputabilis</i> , n. sp.	UNAM	+	<i>Kossmatia exceptionalis</i> (Aguilera) ♀ — here; Burckhardt, 1930 to <i>Steueroceras</i> .
<i>Hoplites bifurcatus</i> , n. sp.	UNAM	+	<i>Kossmatia bifurcata</i> (Aguilera) ♀ — here; Burckhardt, 1930 to <i>Berriasella</i> ; Imlay, 1939 to <i>Parodontoceras</i> .
<i>Hoplites mexicanus</i> , n. sp.	P-USNM	+	<i>Kossmatia bifurcata</i> (Aguilera) ♀ — here; Burckhardt, 1930 to <i>Berriasella</i> ; Imlay, 1939 to <i>Parodontoceras</i> .
<i>Haploceras mazapilensis</i> , n. sp.	—	+	(nom. dub.) <i>Haploceras</i> sp. — here; Burckhardt, 1930 to <i>Haploceras fialar</i> Oppel; Imlay, 1939 to <i>Glochiceras fialar</i> .
<i>Perisphinctes transitorius</i> Oppel	UNAM	—	<i>Aulacosphinctoides lauri</i> (Aguilera) — here; Burckhardt, 1930 to <i>Aulacosphinctes</i> sp.
<i>Pulchellia mexicana</i> , n. sp.	P-USNM	+	<i>Mazapilites mexicanus</i> (Aguilera) — Burckhardt, 1930; Imlay, 1939.
<i>Perisphinctes</i> cf. <i>colubrinus</i> (Reinecke)	UNAM	—	? — Burckhardt, 1930 to " <i>P.</i> cf. <i>lacertosus</i> Font. in Lorio!".

<i>Aspidoceras</i> <i>alamitocensis</i> , n. sp.	P-USNM	+	<i>Aspidoceras alamtocense</i> (Aguilera) + <i>A. cf. A. alamtocense</i> .
<i>Haploceras</i> <i>carinata</i> , n. sp.	—	—	(nom. dub.) <i>Haploceras</i> sp.
<i>Haploceras</i> <i>catorcensis</i> , n. sp.	UNAM	—	" <i>Paraglochiceras</i> " <i>catorcense</i> (Aguilera)
<i>Perisphinctes</i> <i>mazapilensis</i> , n. sp.	—	—	(nom. dub.), <i>Aulacosphinctoides</i> sp.
<i>Perisphinctes</i> <i>colubrinus</i> (Reinecke)	—	—	? (not illustrated).
<i>Perisphinctes</i> <i>felixi</i> , n. sp.	UNAM	+	<i>Aulacosphinctoides lauri</i> (Aguilera) (? ♀).
<i>Perisphinctes</i> <i>lauri</i> , n. sp.	UNAM	+	<i>Aulacosphinctoides lauri</i> ♀ + ? ♂
<i>Perisphinctes</i> <i>pouzinensis</i> Toucas	UNAM	—	? <i>Substeueroceras</i> sp.
<i>Perisphinctes</i> aff. <i>pouzinensis</i>	—	—	? <i>Substeueroceras</i> sp.
<i>Perisphinctes</i> <i>potosinus</i> , n. sp. (Pl. XXIV, fig. 2)	UNAM	+	<i>Pseudoinvoluticeras</i> cf. <i>P. mozambicum</i> Collignon
(Pl. XVII, fig. 1)	UNAM	+	<i>Aulacosphinctoides potosinus</i> (Aguilera) ♀
<i>Perisphinctes</i> <i>dolfussi</i> , n. sp.	UNAM	+	(nom. dub.) <i>Andiceras lenki</i> (Aguilera)
<i>Perisphinctes</i> <i>monserrati</i> , n. sp.	UNAM	+	<i>Andiceras monserrati</i> (Aguilera), ? ♂
<i>Perisphinctes</i> sp. ?	UNAM	+	? <i>Berriasella subprivasensis</i> Krantz
<i>Hoplites cohglani</i> , n. sp.	UNAM	—	<i>Durangites cohglani</i> (Aguilera)
<i>Hoplites heilprini</i> , n. sp.	UNAM	+	<i>Durangites heilprini</i> (Aguilera)
<i>Hoplites</i> sp.	—	+	<i>Kossmatia bifurcata</i> (Aguilera) ♀
<i>Rhacophyllites</i> <i>calderoni</i> , n. sp.	—	—	(nom. dub.) ? <i>Lytoceras</i> sp.
<i>Litoceras</i> <i>potosina</i> , n. sp.	—	—	(nom. dub.) (?) <i>Lytoceras</i> sp.
<i>Placenticeras</i> <i>fallax</i> , n. sp.	UNAM	—	(nom. dub.) <i>Haploceras</i> cf. <i>H. elimatum</i> (Oppel)
<i>Nautilus burkarti</i> , n. sp.	UNAM	—	<i>Physodoceras</i> (n. subgen.) <i>burkarti</i> (Aguilera)
<i>Schloenbachia</i> aff. <i>inflata</i> (J. Sowerby)	UNAM	—	?
<i>Phylloceras</i> cf. <i>welldoe</i> (Michelin)	—	+	<i>Phylloceras</i> sp. juv. ? indet.

It is clear from Table 2 that all of Aguilera's determinations except *Aspidoceras alamtocense* were in need of revision. This revision, based on new collections and Aguilera's remaining type material, shows that of the 25 Jurassic taxa described by Aguilera (in Castillo and Aguilera, 1895) as "new species", only 13 can be identified with certainty, 5 are doubtful and synonyms of the "certain" species, and 7 are *nomina dubia* (based on poor material no longer available and not in new collections).

The following species are here reported from Sierra Catorce for the first time. All specimens are repositied at McMaster University (McM), except for single paratypes of the five new species which are in Mexico (UNAM).

Additional Species (here)	Other Occurrences
<i>Phylloceras</i> cf. <i>P. subplicatus</i> Burckhardt	N. Mexico
<i>Haploceras transatlanticum</i> Burckhardt ?	N. Mexico
<i>H.</i> cf. <i>H. elimatum</i> (Oppel)	S. Europe
<i>Pseudolissoceras zitteli</i> (Burckhardt), ♀ + ? ♂	Argentina, Cuba, S. E. France, North Africa, Iraq
Cf. " <i>Paraglochiceras</i> " sp. indet.	Madagascar
<i>Idoceras</i> cf. <i>I. inflatum</i> Burckhardt	N. Mexico
<i>I.</i> cf. <i>I. mutabile</i> Burckhardt	N. Mexico
<i>I.</i> ex. gr. <i>I. neohispanicum</i> Burckhardt	N. Mexico
<i>Pseudoinvoluticeras</i> cf. <i>P. mozambicum</i> Collignon	Madagascar
<i>Subdichotomoceras</i> , n. sp. aff. <i>S. inversum</i> Spath	Cutch
? <i>Virgatosphinctes fresnosensis</i> Imlay	? N. Mexico
<i>V. sanchezi</i> n. sp., ♀ + ? ♂	—
<i>V.</i> aff. <i>V. communis</i> Spath	Cutch, Madagascar
<i>Aspidoceras</i> cf. <i>A. andinum</i> Steuer	Argentina, Mexico, Europe, Japan
<i>A. haupti</i> Krantz	Argentina
<i>Simoceras</i> cf. <i>S. volanense</i>	Argentina, S. Europe
<i>Berriasella</i> cf. <i>B. picteti</i> (Kilian)	S. E. France
<i>B. lorioli</i> (Zittel) ?	S. E. France
<i>B. subpriasensis</i> Krantz	Argentina
<i>B.</i> aff. <i>B. zacatecana</i> Imlay	N. Mexico
<i>Kossmatia purissima</i> , n. sp.	—
<i>Substeueroceras alticostatum</i> Imlay	N. Mexico
<i>S. storrsi</i> (Stanton)	California
<i>S. catorcense</i> , n. sp. ♀ + ? ♂	—
<i>S. koeneni tabulatum</i> , n. subsp.	? N. Mexico, ? Argentina
<i>Corongoceras mendozanum</i> (Behrendsen)	Argentina
<i>C. cordobai</i> , n. sp., ♀ + ? ♂	—
<i>C.</i> ?, n. sp. indet.	? Argentina
<i>Micracanthoceras acanthellum</i> Imlay	N. Mexico
<i>Durangites acanthicus</i> Burckhardt, ♂	N. Mexico, Cuba
<i>D. vulgaris</i> Burckhardt ♀	N. Mexico
<i>D.</i> n. sp. aff. <i>D. rarifurcatus</i> Imlay	N. Mexico
<i>D. alencasteri</i> , n. sp., ♀ + ? ♂	—
<i>D.</i> ? n. sp. indet.	—

Of the above, *Haploceras* cf. *H. elimatum* and *Pseudoinvoluticeras* cf. *P. mozambicum* are generic and specific revisions of Aguilera's type material; the rest are based on our new material.

GEOGRAPHIC DISTRIBUTION

Species-group level. — The geographic distribution of the Sierra Catorce species tabled below indicates differences in bio-facies from the other Mexican localities within the Mexican Sea, and that the

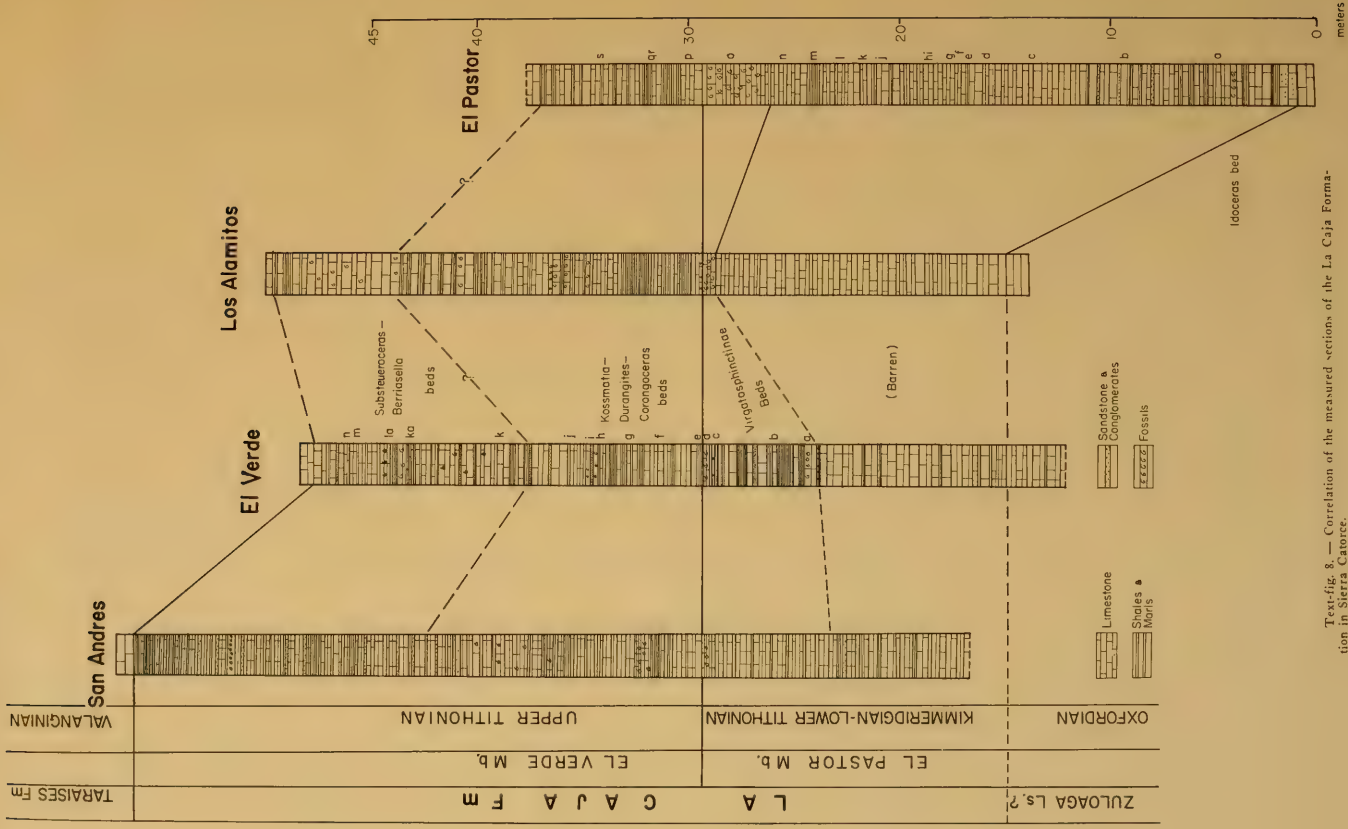
closest affinities were with the Andean basin of Argentina and secondly with Tethys.

Species Distribution	Number	Approx. %
Total in Sierra Catorce	49	
Endemic to Sierra Catorce	20-21	42
Endemic to North America	25-27	53
In common with remainder of Mexico (also Cuba, California)	14	29
In common with Argentina	8-9	17
In common with Europe (most affinities uncertain)	5	10
In common with Indo-Malgache region	4	8

Genus-group level.—Table 4 gives the time correlations between the Tithonian assemblages of Mexico with similar assemblages from other parts of the world, against a bipartite (Enay, 1964) or a tripartite (Arkell, 1956) substage division of the Tithonian. Minor occurrences and those with insufficient stratigraphic data are excluded.

The geographic distribution of the important Upper Jurassic ammonite genera found in the Sierra Catorce is illustrated in Text-figures 30 and 31 (p. 268, 269) on a supposed pre-drift globe of the Late Jurassic. As in the species analysis, it is again evident that the closest affinities of the Tithonian ammonite fauna of Mexico are with Argentina and only secondly with Tethys.

Substeueroeras (including *Parodontoceras*), common in the uppermost Tithonian of Mexico, is found at the same level in Chile, Argentina, California, Oregon, Somaliland, Iraq, and Japan (+ ? France). In Iraq, the genus is said (Spath, 1950) to occur lower in the Tithonian, but the succession is incomplete; Spath (*op. cit.*, p. 133), however, believed in the possibility that the specimens might have come from the topmost Tithonian. *Berriassella* is reported from the Upper Tithonian of Mexico, Argentina, Chile, S. E. France, Iraq, Tunisia, Algeria, Madagascar, N. W. India, and Japan. Except for New Zealand, *Kossmatia* occurs below *Substeueroeras* in all known occurrences (Text-fig. 30). The anachronous occurrence in New Zealand is discussed in the systematic part. The alleged Lower Tithonian age of *Kossmatia* in Algeria (Roman, 1936) has been suggested to be due to a mixture of Upper and Lower Tithonian fossils in the collection (Arkell, 1956, p. 273).

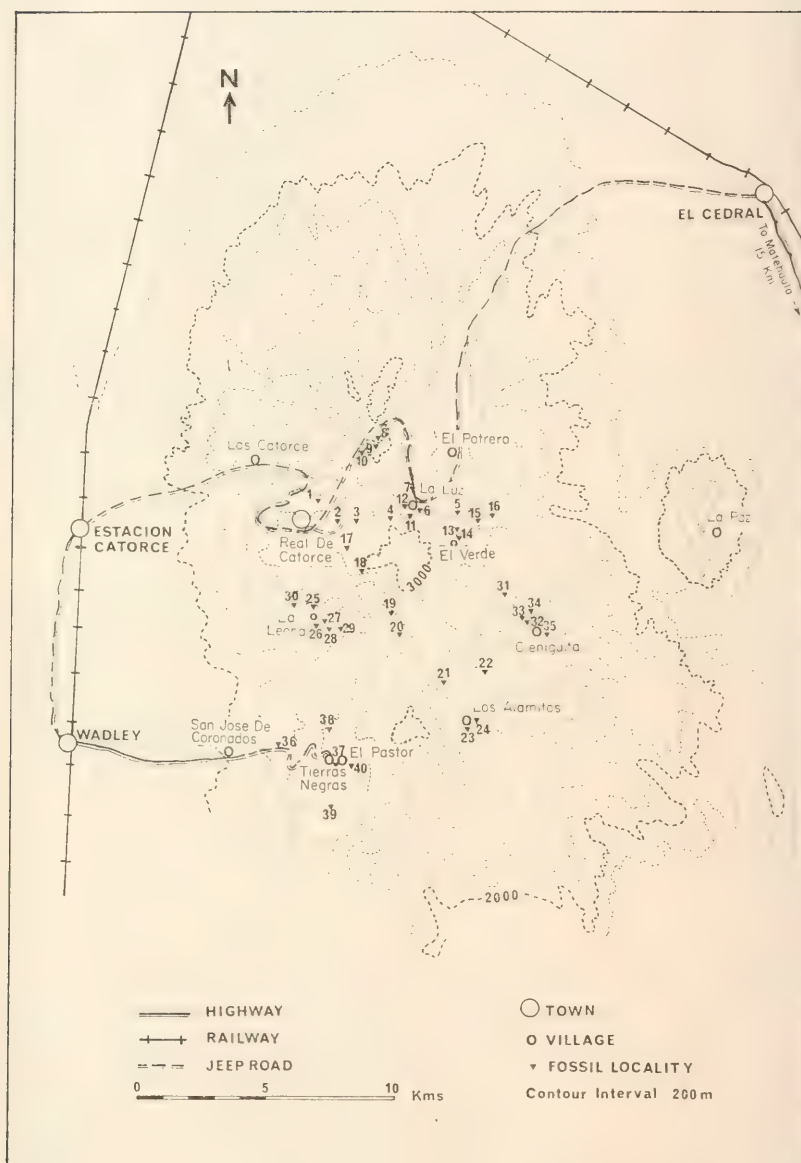


Text-fig. 8. — Correlation of the measured sections of the La Caja Formation in Sierra Catorce.

Durangites, which was hitherto thought to be restricted to Mexico and Cuba, has recently been reported from Turkey and southern Europe (Enay, *et al.*, 1971). However, the supposed occurrence in New Zealand (Hallam, 1971b, fig. 3) was a drafting error (Hallam, *in litt.*). *Corongoceras*, based upon a species from Peru, is also known from the Upper Tithonian of Argentina, Chile, Cuba, Madagascar, Tunisia, and Algeria (?). It is reported here from Mexico for the first time. *Micracanthoceras*, like *Berriasella*, is widespread in Argentina, Mexico, Cuba, Spain, Sicily, Tunisia, Algeria (?), Tanzania, and Cutch.

Concerning the late Lower Tithonian (= Middle Tithonian of some authors) genera found in the condensed Virgatosphinctinae beds, *Aulacosphinctoides* is known also from Argentina, Madagascar, India (Cutch and Spiti), Japan, and New Zealand; *Andiceras* has previously been described only from Argentina; *Virgatosphinctes* is almost cosmopolitan and occurs in the late Lower as well as in the early Upper Tithonian (Table 4).

It should be pointed out here that there is much confusion concerning the stratigraphic ranges of the closely related perisphinctids *Virgatosphinctes*, *Subplanities*, *Aulacosphinctes*, and *Aulacosphinctoides*. This is primarily of a taxonomic nature, due to the different interpretations given to these genera by the different authors. Complete revision of these genera is, therefore, necessary before these difficulties can be removed. According to Zeiss (1968 and *in litt.*) the name *Subplanites* should now be restricted to the Swabian-Franconian forms occurring in the lower part of Lower Tithonian (*Hybonotum* Zone of Zeiss, 1968), *e.g.* the group of *Subplanites contiguus*. Enay (1973, and *in litt.*) believes that true *Virgatosphinctes* occurs only in the Upper Tithonian. His opinion is supported by the occurrence of *Virgatosphinctes* (and *Aulacosphinctoides*) with *Kossmatia* in Nepal (Mouterde, *et al.*, 1971). The forms described by us under *Virgatosphinctes* and *Aulacosphinctoides* occur in association with characteristic late Lower Tithonian (= "Middle Tithonian") *Pseudolissoceras* (here reported from Mexico but also occurring in Argentina, Cuba, Tunisia, France, Iraq) and *Simoceras* (also in S. Europe, N. Africa, Somaliland, Cuba, Argentina). Furthermore the classification of our giant *Virgatosphinctes* is supported by Zeiss (*in litt.*). *Aspidoceras* is



Text-fig. 9. — Fossil localities mainly of the La Caja Formation in the Sierra Catorce.



semicosmopolitan. In Europe, *Aspidoceras* with tubercles and ribs occur at two levels; the first with *A. uhlandi* in the Kimmeridgian Zone of *A. balderus* and the second with *A. rogoznicense* in the "Middle" Tithonian Zone of *Semiformiceras semiforme*. The Sierra Catorce *Aspidoceras* occurrence (except for *A. cf. A. andinum*) is equivalent to the upper level.

The Kimmeridgian *Idoceras* has been reported in great profusion from northern Mexico. This led Arkell (1956) to believe that Mexico was the center of dispersal to Argentina, New Guinea, New Zealand, Sicily, and the Alps.

From the above, it is evident that at the genus level the Mexican Tithonian fauna closely resembles other Tithonian faunas of the Tethyan realm, but particularly also those of Argentina.

AMMONITE ZONES AND CORRELATION

AMMONITE ASSEMBLAGES OF SIERRA CATORCE

The approximate stratigraphic distribution of the ammonite fauna is shown in Table 5. The age is almost entirely Tithonian except for the three tentative species of the Kimmeridgian *Idoceras* found in a single bed and locality (El Pastor) near the base of the La Caja Formation. In the Tithonian, three distinct assemblages are consistently present (from top):

1. *Substeueroceras-Berriasella* assemblage
2. *Kossmatia-Durangites-Corongoceras* assemblage
3. *Virgatosphinctinae* assemblage
4. *Idoceras* assemblage

The first two are Upper Tithonian and the third, upper part of Lower Tithonian (= Middle Tithonian of a three-partite division). There is a barren interval (14-27 m) between assemblage 3 and the small Kimmeridgian assemblage 4. This barren interval corresponds to part of the Kimmeridgian and Lower Tithonian.

The *Virgatosphinctinae* assemblage occurring in the upper part of the El Pastor member of the La Caja Formation, contains the dominant species *Aulacosphinctoides lauri* (Aguil.), *Subdichotomoceras* n. sp. aff. *S. inversum* Spath, *Andiceras lenki* (Aguil.), *A. monserati* (Aguil.), *Pseudolissoceras zitteli* (Burck.), and *Virgatosphinctes sanchezi*, n. sp. Of these, *Andiceras* and *Aulacosphinctoides* occur in great profusion. Accessories are *Phylloceras* cf. *P. subplicata*.

tius Burck., *P. sp. juv. ? indet.*, *Aspidoceras alamitocense* Aguil., *A. cf. A. andinum* Steuer, *A. haupti* Krantz, *Simoceras cf. S. volanense* (Oppel), *Haploceras transatlanticum* Burck. ?, "*Paraglochiceras*" *sp. indet.*, *Mazapilites mexicanus* (Aguil.), ? *Virgatosphinctes fresnosensis* Imlay, and *Virgatosphinctes aff. V. communis* Spath. This assemblage is best known from the localities El Pastor and Los Alamitos. Near Real de Catorce, the *Virgatosphinctinae* beds are thicker developed but less fossiliferous, and the correlation with the sections at Los Alamitos and El Pastor is based partly upon the common occurrence of *Subdichotomoceras n. sp. aff. S. inversum*.

The *Kossmatia-Durangites-Corongoceras* assemblage comes from the lower 10 m of the El Verde Member of the La Caja Formation and contains abundant *Kossmatia alamitosensis* (Aguil.), *K. bifurcata* (Aguil.), *K. exceptionalis* (Aguil.), *K. flexicostata* (Aguil.), *K. purissima*, n. sp., *Durangites vulgaris* Burck., *D. alencasteri*, n. sp., *D. heilprini* (Aguil.), *Corongoceras mendozanum* (Behr.), and *C. cordobai*, n. sp. Less abundant are *Micracanthoceras acanthellum* Imlay, *Durangites acanthicus* Burck., *D. n. sp. aff. D. rarifurcatus* Imlay, and *D. ? n. sp. indet.* A few specimens of *Substeueroceras catorcense*, n. sp. may also have come from this assemblage.

The *Substeueroceras-Berriasella* assemblage, from the upper 10 m of the El Verde Member includes as major elements *Substeueroceras alticostatum* Imlay, *S. koeneni tabulatum*, n. subsp., *S. catorcense*, n. sp., *S. storrsi* (Stanton), *Berriasella cf. B. picteti* (Kilian), *B. lorioli* (Zittel) ?, *B. subprivansensis* Krantz, and *B. aff. B. zacatecana* Imlay.

COMPARISON WITH NORTHERN MEXICO

The ammonite assemblages and the deduced biostratigraphic subdivisions of the Mexican Upper Jurassic (Oxfordian excluded) according to different workers are chronologically summarized in Table 6, along with the ages assigned to them by the respective authors. The four columns of Imlay (1939, 1943, 1952, Imlay and Jones, 1970) illustrate the different interpretations and definitions of the stages; there has never been unanimity of opinion regarding the definition and correlation of the Upper Jurassic zones and

stages as originally defined in northwest Europe. Table 7 illustrates the critical correlations of the Upper Jurassic zones and stages (excluding the Oxfordian) in Europe. A full discussion of the problem is beyond the scope of this work. As far as the Tithonian stage is concerned, the authors are in agreement with the opinions of Enay (1964, 1973).

For the Jurassic of northern Mexico, only a few modifications were made to the biostratigraphic scheme proposed by Burckhardt (1930) (Table 6). The most important of these is the placing by Imlay (1939) of the beds bearing *Proniceras* above rather than below *Kossmatia* on the basis of field evidence. Also the interval with "*Hoplites* ex gr. *koellikeri*" Oppel, 1863 (*non* Haupt, 1907) at San Pedro del Gallo which Burckhardt had distinguished between the *Kossmatia* Beds and *Substeueroceras* Beds, was included in the "*Kossmatia* and *Durangites* Beds". Cantu Chapa (1963) included *Kossmatia* in his listing of Lower Tithonian genera, along with *Virgatosphinctes*, *Subplanites* and *Mazapilites*; however, his own material apparently did not include any *Kossmatia*.

The last column of Table 6 gives the correlation of the Sierra Catorce assemblages within the Mexican Jurassic. The Tithonian stage is used in the sense of the Luxembourg Resolution number 5 of Enay (Colloque du Jurassique, Luxembourg 1962, publ. 1964). Regarding substages, we have here adopted the bipartite division presented by Enay (1964) rather than the tripartite one of Arkell (1956). There is general agreement between the successions of the Sierra Catorce and of northern Mexico as recently presented by Imlay and Jones (1970; with tripartite division), with the exception of some significant and some apparent differences:

1. *Proniceras* which lies together with *Substeueroceras* in the uppermost Tithonian of northern Mexico is missing in Sierra Catorce.
2. *Hildoglochiceras* is not represented in Sierra Catorce.
3. *Micracanthoceras* is extremely scarce and occurs only in the lower part of Upper Tithonian.
4. In Sierra Catorce, "*Parodontoceras*" occurs only together with *Substeueroceras* and does not seem to range downwards as in northern Mexico.
5. In our succession, *Mazapilites* was found only in the *Virgatosphinctinae* beds (based on three specimens of which two were *in situ*) whereas it occurs below these beds in northern Mexico.

BURCKHARDT 1930 "beds"		SPATH 1933, IMLAY 1939 (assemblages)		IMLAY 1943 (assemblages)		SPATH 1950 (beds)		IMLAY 1952 (assemblages)		ARHELL 1956 (zones)		CANTU CHAPA 1963 (zones)		IMLAY & JONES 1970 (charact. fossils)		HEREIN (assemblages)	
PORTLANDIAN U. L.	"Steueroceras" (Substeueroceras)	TITHONIAN	Substeueroceras	TITHONIAN	Substeueroceras	TITHONIAN	Substeueroceras	PORTLANDIAN	Substeueroceras	TITHONIAN	Substeueroceras koeneni (also Micracanthoceras, Proniceras etc.)	U.	Substeueroceras Proniceras	U.	Substeueroceras Proniceras	U.	Substeueroceras — Berriasella
	"Hoplites ex gr. koellikeri" & Kossmatia		Proniceras		Microacanth= oceras		Proniceras		Microacanth= oceras		Durangites	Hildogloch= iceras	?		"Paradonto= oceras"		Kossmatia — Durangites — Corongoceras
	Proniceras		Kossmatia		Hildogloch= iceras		Kossmatia		Durangites		?	Corangoceras					
	"Aulacosphinctes"	U.	Torquatisphinctes	PORTLANDIAN	Subplanites	Aulacosphinct= oides	MESO- Pseudolissoceras	PORTLANDIAN	?	Aulacosphinct= oides	Virgatosphinctes Aulacosphinctoides Subplanites	L.	Kossmatia Virgatosphinctes	M.	?	(M)	Virgatosphinctinae
	Mazapilites				U.				Mazapilites		EO- Pseudocolubrinus		Mazapilites		Mazapilites Hybonoticeras		Subplanites Mazapilites
	"Wuagenia" (Hybonoticeras) Sutneria	M. + L.	Hybonoticeras	Hybonoticeras	KIMMERIDGIAN	Hybonoticeras	M.	Hyb. beckeri	M	Hybonoticeras beckeri		?		Idoceras			
	Haploceras ex gr. fialar							Glochiceras ex gr. fialar Idoceras ex gr. durangense		Glochiceras fialar Idoceras durangense		Idoceras durangense Glochiceras fialar			Idoceras durangense I. ex gr. balderum		
Idoceras	L.	Idoceras ex gr. balderus	Idoceras ex gr. balderus Sutneria ex gr. platynota	Idoceras ex gr. balderus Sutneria ex gr. platynota	Idoceras ex gr. balderus	L.	?	L.	Sutneria ex gr. platynota								

TABLE 6.—History of faunal divisions and stages applied to the Upper Jurassic (excluding Oxfordian) of Mexico.

6. *Hybonoticeras* is missing in our collections, possibly because the equivalent beds are barren, i.e. the interval separating the *Idoceras* horizon from the *Virgatosphinctinae* beds.

7. The entire known Kimmeridgian fauna of Sierra Catorce consists of ill-preserved specimens of three species of *Idoceras* from a single bed and outcrop, i.e. El Pastor. The occurrence of pebbles of Zuloaga Limestone at the base of the La Caja Formation below the *Idoceras* bed (Pl. 24, fig. 1) indicate that a large part of the Kimmeridgian is missing due to an erosional unconformity.

ZONAL CORRELATION

The *Idoceras* assemblage of Sierra Catorce is of Kimmeridgian age but cannot be correlated at the zone level in the absence of unqualified specific determinations and of other associated ammonite fauna.

The *Virgatosphinctinae* assemblage combines the elements of two Lower Tithonian ammonite zones distinguished by Burckhardt (1903) in Argentina, i.e. the Zones of *Pseudolissoceras zitteli* and of *Virgatosphinctes mendozanus*. The occurrence of *P. zitteli* (Burckhardt) in our assemblage is noteworthy because the species is also known from the late Lower Tithonian of such widely separated areas as Tunisia (Arnould-Saget, 1951, *vide* Enay, 1964), Iraq (Spath, 1950), southeastern France (Donze and Enay, 1961) and southern Germany (Barthel, 1962). The associated genera *Virgatosphinctes* and *Aulacosphinctoides* have similarly wide geographical distribution in the lower Tithonian (see Table 4; Text-fig. 31). The *Virgatosphinctinae* beds are, therefore, correlated with both the *P. zitteli* and *V. mendozanus* Zones of Argentina.

The *Kossmatia-Durangites-Corongoceras* assemblage of northern Mexico is probably, at least in part, equivalent to the Argentine Zone of *Corongoceras alternans* of Lanza (1945). The *C. alternans* Zone includes several similar or even identical elements to Mexico such as *Corongoceras mendozanum* (Behrendsen) but differs in the abundant presence of *Berriasella* spp. which in Mexico only appear in the higher *Substeueroceras-Berriasella* assemblage. The possibility, therefore, exists that either the appearance of *Berriasella* is diachronous (earlier in Argentina and Europe) or that the *C. alternans* Zone is equivalent to the *Kossmatia-Durangites-Corongoceras* assemblage plus part of the *Substeueroceras-Berriasella* as-

semblage (or both). Significantly, the zone underlying the *C. alternans* Zone in Argentina, i.e. the Zone of *Windhauseniaceras internispinosum*, also of Leanza (1945), appears to bear an entirely endemic ammonite fauna.

The poorly known assemblage of Krantz's (1928) Argentine Zone of "*Kossmatia*" *pseudodesmidioptycha* is of uncertain age; "*K.*" *pseudodesmidioptycha* Krantz is of dubious generic affinity bearing a mid-ventral smooth band and widely spaced ribs apparently with lateral tubercles on the inner whorls — all characters foreign to *Kossmatia*. The inclusion by Spath (1950) of this dubious zone into his earlier (Spath, 1923) Indo-Pacific Zone of *Kossmatia tenuistriata*, based on *K. tenuistriata* (Gray) from uncertain levels of the Himalayas and unknown from the Americas, appears absurd.

The Argentine *C. alternans* Zone is probably equivalent to the Zone of *Berriasella delphinensis* in southeastern France (Enay, 1964) which, in turn, is correlated with the upper part of the Alpine Zone of *Virgatosphinctes transitorius* (see Table 7).

The *Substeueroceras-Berriasella* assemblage of Sierra Catorce closely resembles that of the Argentine Zone of *Substeueroceras koeneni* which was originally proposed by Gerth (1925) and accepted by later workers including Burckhardt (1930), Windhausen (1931), Weaver (1931), and Leanza (1945). The Catorce assemblage includes *S. koeneni* (Steuer) with the new subspecies *S. k. tabulatum*, as well as other representatives of the zonal assemblage. The *S. koeneni* Zone is, therefore, extended to Mexico. It is clearly uppermost Tithonian (Table 4) age and equivalent to the Zone of *Berriasella chaperi* in southeastern France and to the upper part of the Zone of *Virgatosphinctes transitorius* of the Alpine region (Enay, 1964).

PALEOGEOGRAPHY

The previous paleogeographic reconstruction of Mexico during the Late Jurassic, particularly by Burckhardt (1930) and Imlay (1939, 1940, 1943a, 1943b), has essentially remained unchanged. The Mexican Sea (Text-fig. 32, p. 270) was extended lengthwise through northern and central Mexico. It was open in the southeast and probably intermittently also in the southwest (Balsas Portal). The Coahuila Peninsula divided the basin in the north and the narrow elongate Tamaulipas Peninsula separated it from the Gulf. The

REPRESENTATIVES OF THE THREE MAJOR PROVINCES, ZEISS 1968				LUXEMBOURG RESOLUTIONS 1962 (ENAY 1964)			
S. ENGLAND		S. E. FRANCE		RUSSIAN PLATFORM		No. 4: BRIT. MESOZ. COM (AGER 1963)	
PORTLANDIAN	Titanites giganteus	Berrasella chaperi	Epiragmites nikitini	VOLGIAN	PORTLANDIAN	VOLGIAN	U KIMM = DORSETIAN SUBSTAGE
	Glaucolithes garei	U Berrasella delphinensis	Viragites virgatus				
	Zaraiskites albanii	(Pseudoviragites scruposus)	M Zaraiskites zarajskensis				
	Pavlovia pallasioides	M Semiformiceras semiforme	Zaraiskites disprosopus				
	Pavlovia rotunda		Pavlovia pavlovi				
	Pectinolithes pectinatus	Perapallisceras antiquum Franconites aff. vimineus	Ilowaysky pseudoscypha				
	Arkelites hudsoni	Neochetoceras stercoroides	Ilowaysky sokolovi				
KIMMERIDGIAN	Gravesia gigas & gravesiana	Glochiceras lithographicum	Subplanites klimovi				
L	Aulacostephanus antissiodorensis	Hyboniticeras beckeri	Virgatoliteceras fallax				
	Aulacostephanus eudoxus	Taramelliceras klettgowianum	Aulacostephanus pseudomutabilis				

TABLE 7. — Equivalence of Upper Jurassic stages (excluding Oxfordian) and zones from different faunal provinces. Note differences of zones for SE France from Table 4.

Upper Jurassic was mainly a time of transgression except for some regression towards the close of the period.

According to Burckhardt (1930, p. 71, 102) and Imlay (1938, p. 1660), the La Caja Formation in Zacatecas State and Durango State of northern Mexico, was deposited in fairly calm waters of the outer neritic zone. Burckhardt had based his argument on the relative scarcity of clastic sediments and benthic fossils (bivalves and brachiopods). Our studies indicate that in the Sierra Catorce, bivalves and brachiopods were extremely abundant in the Virgatosphinctinae beds and that at least these beds originated in shallow waters; the relatively high clastic fraction throughout the La Caja also indicates more shallow water condition than in northern Mexico. Furthermore most of the ammonite fauna in Sierra Catorce consists of highly ornate planulate shells; smooth involute shells like *Haploceras* and *Mazapilites*, as well as phylloceratids and lytoceratids, are rare, in contrast to northern Mexico. Presuming that ornate planulate shell forms were adapted to high energy environments (Westermann, 1971) their abundance in Sierra Catorce also supports shallow water deposition.

The migration route between the Mexican and Argentine (Andean) Upper Jurassic basins was probably through the Balsas Portal, which according to Imlay (1940) was open at this time. However, the Atlantic Ocean and the Pacific Ocean were probably also connected farther south, in the Costa Rica-Panama area.

The differentiation of the Upper Jurassic ammonoid fauna into the Boreal, Tethyan, and Pacific Realms (Arkell, 1956) has been the subject of much discussion. Among the recent authors are Imlay (1965), Stevens (1967), and Hallam (1969a, 1971b). Earlier, Burckhardt (1910, 1911) believed that the Mexican Upper Jurassic had some genera in common with those of the Boreal Realm, *e.g.* alleged *Virgatites*, *Craspedites*, and *Simbirskites*; but this view was already opposed by Uhlig (1910) and the current belief (Arkell, 1956, p. 582) is that Burckhardt's alleged affinities were due to misidentifications. Similarly, Leanza (1945) favoured Boreal affinities for some of his Argentine fauna. We have failed to find any true Boreal forms in the Sierra Catorce fauna. Stevens (1967) merged the Pacific Realm with the Tethyan Realm because of the existence of an Indo-Pacific Province. Hallam (1969) recognized

only the Boreal Realm and the Tethyan Realm, and distinguished within the latter the Ethiopian Province and Indo-Pacific Province. Enay (1973) distinguishes three provinces within the Tethyan Realm, *i.e.* (i) the Mediterranean Province either in Lower/Middle or Upper Tithonian which corresponds to the lands bordering the present Mediterranean Sea extending to the east as far as Kurdistan and to the west as far as Mexico with extensions to California and to Argentina; (ii) the Himalayan or Indo-Pacific Province (which manifests itself best in the Upper Tithonian) extending from India through New Guinea to Australia, New Zealand, and possibly Japan; (iii) and the Ethiopian Province (distinguished particularly in the Lower (*s. str.*) and Upper Tithonian) with extensions to Somaliland, Arabia, Central Persia, and Afghanistan.

SYSTEMATIC DESCRIPTIONS

MEASUREMENTS AND ABBREVIATIONS

All measurements are in millimeters; they include the ornament and, with rare exceptions, are taken on the internal mold (Text-fig. 10).

D=Maximum diameter at a given growth stage.

U=Diameter of umbilicus measured at seam.

H=Height of whorl measured in the plane of coiling.

W=Maximum width of whorl at right angles to the plane of coiling.

P=Number of primary ribs on the umbilical shoulder from a given D apicad to 90° ($P/1/4$ Wh.), 180° ($P/1/2$ Wh.), or 360° ($P/Wh.$) as indicated.

S=Number of secondary ribs on venter from a given D apicad to 90° ($S/1/4$ Wh.), 180° ($S/1/2$ Wh.) or 360° ($S/Wh.$) as indicated.

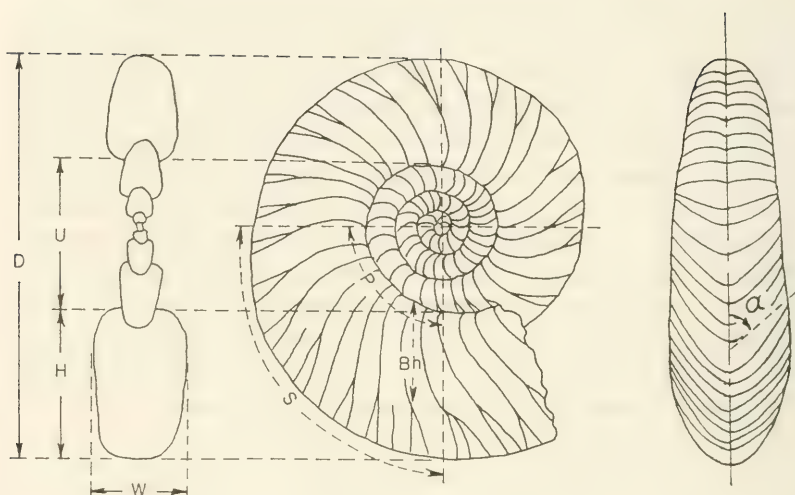
Bh=Length of a primary rib from umbilical shoulder to point of bifurcation, measured as the shortest distance between the end points.

α =Angle of inflection of secondary rib on the venter.

Two or more sets of measurements for one specimen were taken at 90° intervals. In most cases measurements of only the figured and better preserved specimens are given (for complete tables of measurement of all the studied specimens see Verma, 1972). All measurements are of the phragmocone unless stated otherwise.

REPOSITORIES

All specimens collected by Verma are deposited in the Geology Department, McMaster University, Hamilton, Ontario, Canada (McM), with the exception of single paratypes of the five new species and one subspecies which are in the Instituto de Geología,



Text-fig. 10. — Schematic diagram to illustrate the shell parameters.

Universidad Nacional Autónoma de México, Mexico City, D. F., Mexico (UNAM). The latter institute also has a large part of the type specimens of Aguilera (*in* Castillo and Aguilera, 1895), while the remainder are either available only as plaster casts in the United States National Museum, U. S. Geological Survey, Washington, D.C. (P—USNM), or appear to have been lost (see Table 2).

ORDER AMMONOIDEA

Suborder PHYLLOCERATINA Arkell 1950

Superfamily PHYLLOCERATACEAE Zittel, 1884

Family PHYLLOCERATIDAE Zittel, 1884

Subfamily PHYLLOCERATINAE Zittel, 1884

Genus PHYLLOCERAS Suess, 1865

Type species: *Am. heterophyllus* J. Sowerby, 1820.

Phylloceras cf. **P. subplicatus** Burckhardt, 1912

Pl. 25, figs. 1-2

1906. *Phylloceras apenninicum* Canavari, Burckhardt, Inst. Geol. México, Bol. 23, p. 106, pl. XXVIII, figs. 1-5.

?1912. *Phylloceras subplicatus* Burckhardt, *id.*, Bol. 29, p. 40, pl. VII, figs. 1-6.

Material. — One complete internal mold of phragmocone with test remains on venter from loc. 23B (McM - J 1506/386); one well-preserved phragmocone fragment with test from loc. 40E (McM - J 1529/141).

Description. — Although little test is preserved on the larger specimen, it appears to be conspecific with the smaller one. The shell is strongly compressed and involute with subovate whorl section, about twice as high as wide. The flanks are weakly convex and the venter is sharply rounded. The shell surface of the outer flanks and venter is covered with fine dense slightly flexuous riblets. Superimposed upon these are, regularly spaced, broad, similarly flexed radial folds or undulations on the middle and outer parts of the flank. Weaker folds may be interspaced. On the flanks of the internal mold, the undulations are visible in oblique light. The septal suture has intensely subdivided saddles, in general triphyllic and quadriphyllic but without well-developed rounded endings.

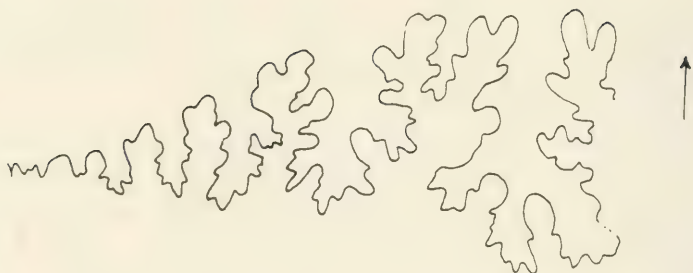
Remarks. — In the spacing of ribs and lateral undulations, our specimens closely resemble "*P. appenninicum* Canavari" of Burckhardt (1906) which is probably conspecific with *P. subplicatus* Burckhardt (1912). Due to the scarcity of material, no attempt is made here to find older synonyms of Burckhardt's supposed species. *P. subplicatus* is said to be distinct only by more irregularly spaced and unequal undulations. *P. plicatus* Uhlig (1910, p. 4, pl. II figs. 4, 5) from Spiti, has more strongly flexed riblets, and thinner and more numerous lateral folds. *P. knoxvillense* Stanton (1896, p. 72, pl. 14, figs. 1-3, refigured by Imlay and Jones, 1970 p. B28, pl. 2, figs. 4-11) from California differs from *P. subplicatus* by strong radial constrictions. *P. glennense* Anderson (1945, p. 976, pl. 11, figs. 1-2, also refigured by Imlay and Jones, 1970, p. B28, pl. 1, figs. 9,10) has coarser more flexuous riblets and less prominent lateral folds.

Occurrence. — Virgatosphinctinae beds, upper part of El Pastor Member, La Caja Formation, Sierra Catorce.

Age. — Upper part of Lower Tithonian.

Measurements. —

	D	U	U/D	H	W	H/W
McM - J 1506/386	130.0	15.0	0.11	68.0	37.0	1.83
- J 1529/141	—	—	—	51.0	31.0	1.64



Text-fig. 11. — Septal suture of *Phylloceras* ? sp. juv. indet., McM - J 1509/339, at H = 24 mm.

***Phylloceras* ? sp. juv. indet.**

Pl. 25, figs. 3-4; Text-fig. 11

?1895. *Phylloceras* cf. *velledoe* (Michelin), Aguilera in Castillo and Aguilera, Com. Geol. México, Bol. 1, p. 13, pl. VI, fig. 9.

Material. — Fourteen small internal molds of phragmocones with minor test remains in different modes of preservation: four from loc. 23A (McM - J 1505/186-188, 198); eight from loc. 23B (McM - J 1506/91, 211, 220, 391-394, 396); one from loc. 24 (McM - J 1509/339); one from loc. 25 (McM - J 1517/88).

Description. — The shell is obvolute and compressed with elliptical whorl section. The flanks are weakly convex and the venter is narrowly rounded. The surface ornament of the shell is generally unknown, except for the presence of dense weak riblets on the venter of some specimens. Constrictions or ventral flares appear to be absent. The septal suture (Text-fig. 11) of specimen J 1509/339 at 24 mm whorl height is almost ammonitic rather than phylloid. Some specimens have terminal approximated sutures indicating adulthood.

Remarks. — The septal suture, at least of some specimens, is reminiscent of some *Calliphyloceras* figured by Geczy (1967, pp. 22-45, pls. V-XIII, LXIII, LXIV), of which a few also seem to miss constrictions or flares. A specimen described by Aguilera (1895) as *Phylloceras* cf. *velledoe* is not available in Mexico; from its poor illustration, it appears to be similar to our specimens.

Occurrence. — All specimens except J 1517/88 come from Virgatosphinctinae beds, upper part of El Pastor Member, La Caja

Formation, Sierra Catorce. J 1517/88 is from the El Verde Member of the same section.

Age. — Lower Kimmeridgian to Upper Tithonian.

Measurements. —

	D	H	W	H/W
McM - J 1505/186	19.0	10.7	8.0	1.33
- J 1505/187	38.0	23.0	14.5	1.62
- J 1505/188	24.5	15.5	10.0	1.55
- J 1505/198	39.5	22.0	15.0	1.46
- J 1506/91	42.0	27.0	16.5	1.63
- J 1506/211	c.31.0	c.18.5	c.12.5	1.48
- J 1506/220	31.0	20.0	c.12.5	1.60
- J 1506/391	34.0	20.0	15.0	1.33
- J 1506/392	29.0	17.5	12.0	1.45
- J 1506/393	27.0	16.5	10.0	1.65
- J 1506/394	18.5	11.5	8.0	1.43
- J 1509/339	41.0	24.0	16.0	1.50
- J 1517/88	48.5	29.0	c.22.0	1.31

Suborder AMMONITINA Hyatt, 1889

Superfamily HAPLOCERATACEAE Zittel, 1884

Family HAPLOCERATIDAE Zittel, 1884

This family is represented in the collection by about 50 small specimens of *Haploceras* Zittel, *Pseudolissoceras* Spath, and "*Paraglochiceras*" Collignon. The material, however, is in a poor state of preservation; the surface ornament characterizing *Haploceras* has been largely weathered. The smooth *Pseudolissoceras* species can be identified on dimensional attributes and septal sutures. The following identifications are made on the basis of whorl section, degree of involution, septal sutures and, wherever possible, surface ornament.

Genus HAPLOCERAS Zittel, 1870

Type species: *Ammonites climatus* Oppel in Zittel, 1868 (SD Spath, 1923).

Haploceras transatlanticum Burckhardt ?, 1906

Pl. 26, figs. 1-2

?1906. *Haploceras transatlanticum* Burckhardt, Inst. Geol. México, Bol. 23, p. 83, pl. XI, figs. 1-8, 13-15.

Material. — Eleven small specimens, mostly phragmocones, generally poorly preserved: two from loc. 23A (McM - J 1505/193,

270); nine from loc. 23B (McM - J 1506/74, 210, 218, 219, 221, 387-389, 390).

Description. — The shell is planulate, moderately evolute, with compressed, subovate whorl section, moderately deep umbilicus and steep umbilical wall. The flanks are weakly convex and the venter is rounded. The surface is smooth.

Remarks. — In thickness, whorl section and coiling, our specimens are similar to *H. transatlanticum* Burckhardt (1906) which has faint falcoid striae-like riblets on the test. However, our specimens have suffered strong corrosion resulting in complete loss of ornament. *H. aff. transatlanticum* of Burckhardt (1906, p. 85, pl. XXI, figs. 9-12) appears to have smooth test but differs in the details of the septal suture. Another closely related species is *H. felixi* Burckhardt (1906, p. 93, pl. XXIV, figs. 11-15) which has more prominent falcoid ribbing. Most of the other Mexican species of *Haploceras* are either less inflated or have a much more pronounced ornament. Burckhardt (1930, p. 80) also indicated the occurrence of his *H. aff. transatlanticum* in the Sierra Catorce. A study of Burckhardt's monographs indicates that the different Mexican species of *Haploceras* and of the related *Glochiceras* and *Hildoglochiceras* are in need of taxonomic revision. This would necessitate new collections from the Mazapil area where these genera occur in profusion and in a far better state of preservation than in the Sierra Catorce. A small collection by Westermann indicates the presence of dimorphism in *Haploceras*.

Occurrence. — Virgatosphinctinae beds, upper part of El Pastor Member, La Caja Formation, Sierra Catorce.

Age. — Upper part of Lower Tithonian.

Measurements (better preserved specimens). —

	D	U	U/D	H	W	H/W
McM - J 1505/193	28.0	5.5	0.19	15.0	12.5	1.20
- J 1506/74	48.0	10.0	0.20	24.0	16.0	1.50
- J 1506/218	31.0	7.5	0.24	16.0	12.5	1.28
- J 1506/219	33.5	8.0	0.23	16.0	11.0	1.45
- J 1506/221	34.0	8.0	0.23	16.5	15.0	1.10
- J 1506/389	36.0	7.0	0.19	17.0	14.0	1.21
- J 1506/390	23.0	5.0	0.21	12.0	9.0	1.33

Haploceras cf. **H. elimatum** (Oppel, 1865, Zittel), 1868 Pl. 29, fig. 2

?1865. *Ammonites elimatus* Oppel, Z. deutsch. geol. Ges., vol. 17, p. 549.

?1868. *Ammonites elimatus* Oppel, Zittel, Palaeont. Mitt. Mus. k. Bayer. Staates, Band 2, p. 79, pl. 13, figs. 1-7 [SD Spath, 1923].

?1895. *Placenticerias fallax* Aguilera in Castillo and Aguilera, Com. Geol. México, Bol. 1, p. 17, pl. VIII, figs. 1, 2 [*nom. dub.*].

Material. — The holotype (only specimen) of “*Placenticerias fallax*”, probably an adult poorly preserved specimen, *i.e.* crushed phragmocone and ? 1/2 whorl incomplete body chamber (UNAM 12), from the “Cieneguita Beds” of “Rancho Alamitos”, Sierra Catorce.

Description. — The shell is large for *Haploceras* ($D = 105$ mm), involute and discoidal, with compressed ovate to subtrapezoidal whorl section of the body chamber; the venter is well-rounded on the phragmocone and slightly flattened on the body chamber. The body chamber, according to the remaining impression of the egressing umbilical seam, was approximately 1/3 whorl longer than preserved and the complete diameter is estimated at 115-120 mm. The test which is partly preserved, is smooth except for dense flexed growth lines visible on the phragmocone; their flexuous shape, however, may be partly due to the irregular crushing.

Remarks. — This single imperfect specimen is here considered insufficient to typify the new species “*Placenticerias fallax*” Aguilera which is, therefore, a *nomen dubium*. Furthermore, this specimen closely resembles the lectotype of *Haploceras elimatum*, the type species of *Haploceras* by subsequent designation of Spath (1923, *vide* Treatise, vol. L, p. 273), from the Tithonian of Stramberg in the Alps (refigured in the Treatise, vol. L, fig. 316). According to Zittel (1868, p. 80), who properly described the species for the first time, the species reaches 145 mm diameter at Stramberg. The several species described from Mexico by Aguilera (*in* Castillo and Aguilera, 1895) and Burckhardt (1906) are mostly much smaller and more compressed than “*P. fallax*”; the largest poorly known one, “*H. Ordonezi* Aguilera” (*in* Burckhardt, 1906, p. 94, pl. XXVI, figs. 1-8), also has falcoid lirae which are missing in “*P. fallax*”.

Occurrence. — The nature of the matrix is similar to that of the Virgatosphinctinae beds of Los Alamitos (loc. 23B of this work).

Age. — Upper part of Lower Tithonian.

Measurements. —

	D	U	U/D	H	W	H/W
Holotype "P. fallax"	c.105.0	14.5	0.138	57.0	32.0	1.78

Genus **PSEUDOLISSOCERAS** Spath, 1925

Type species: *Neumayria zitteli* Burckhardt, 1903 (SD Roman, 1938).

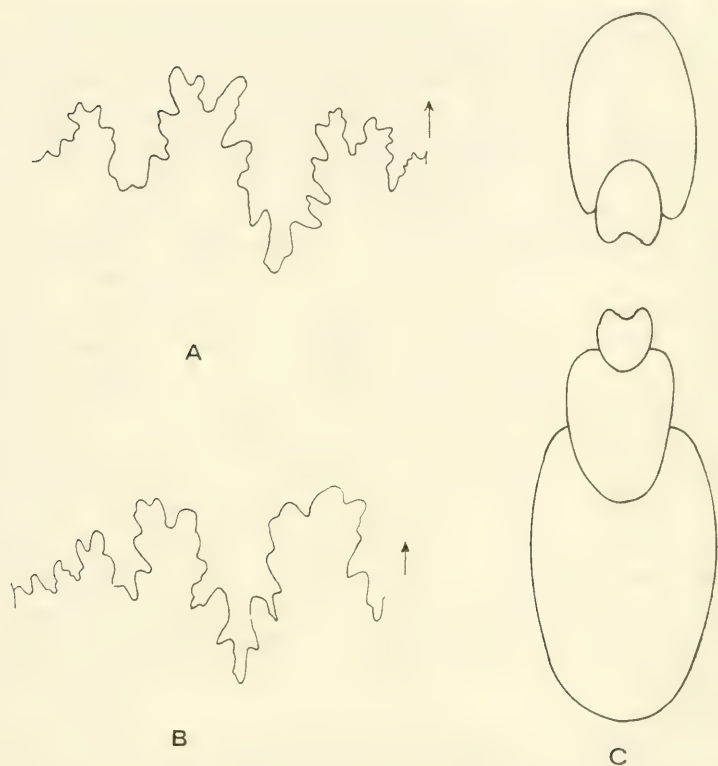
Pseudolissoceras zitteli (Burckhardt), 1903 [♀ + ?♂]

Pl. 26, figs. 3-5; Text-figs. 12-13

1903. *Neumayria zitteli* Burckhardt, Palaeontographica, vol. 50, p. 55, pl. X, figs. 1-8 [?♀].
 ?1906. *Neumayria subrasilis* Burckhardt, Inst. Geol. México, Bol. 23, p. 127, pl. XXXIV, figs. 8-10 [?♂].
 ?1906. *Neumayria* aff. *subrasilis* Burckhardt, *ibid.*, p. 128, pl. XXIV, figs. 11-14 [?♂].
 1925. *Pseudolissoceras zitteli* (Burckhardt), Spath, Monogr. Hunter. Mus., No. 1, p. 113 [*gen. nov.*, type species].
 1928. *Pseudolissoceras zitteli* (Burckhardt), Krantz, Acad. Nac. Cienc. Rep. Argentina, p. 18, pl. I, fig. 6 [?♀].
 1930. *Pseudolissoceras subrasile* (Burckhardt), Burckhardt, Mem. Soc. Paléont. Suisse, vol. 2, p. 47 [*gen. nov.*].
 1942. *Pseudolissoceras* cf. *P. zitteli* (Burckhardt), Imlay, Geol. Soc. America, Bull., vol. 53, p. 1443, pl. 4, figs. 1-3 [?♀], 4, 7, 8, 11, 12 [?♂].

Material. — Twenty-six phragmocones of which 10 (? + 2) are probably macroconchs and about 14 microconchs: two from loc. 23A (McM - J 1505/197, 199); 15 from loc. 23B (McM - J 1506/75, 76, 80-85, 88, 213, 214, 216, 333, 387); five, *ex situ* from Los Alamitos (McM - J 1509/212, 234, 333, 336, 349); two from loc. 30 (McM - J 1516/10, 29); two from loc. 14A (McM - J 1526/63, 64). Of the above, J 1509/333 and J 1506/387 are the largest and best preserved macroconchs, while J 1506/213, J 1509/2, J 1516/10, 29 and J 1526/63, 64 are well-preserved (?) microconchs.

Description. — The apparent macroconch (♀) is relatively large for the genus (D phragmocone $\leq$ 62 mm), and strongly compressed, moderately evolute. The whorl section is compressed, subovate (Text-fig. 12C). Whorl overlap is about 25%. The narrow umbilical wall is almost vertical. Except for some faint radial striations, the shell is entirely smooth. The septal suture (Text-fig. 12A; H = 21.5 mm) shows a shallow E, a deeper L and a short



Text-fig. 12. — Septal sutures and cross section of *Pseudolissoceras zitteli* (Burckhardt). A. Macroconch [♀], McM - J 1506/387, at H = 21.5 mm. B. Microconch [♂], McM - J 1516/10, at H = 7.5 mm. C. Macroconch [♀], McM - J 1509/333, $\times 1.5$.

E/L saddle. However this suture has begun to approximate indicating end of growth. In the largest specimen (McM - J 1509/333) with phragmocone diameter of 62 mm (H = 25 mm), egression of the whorls has already begun one-half whorl before the end.

The apparent microconch (δ) is much smaller than the macroconch (D Phragmocone ≤ 18 mm) but has similar whorl shape and coiling (Text-fig. 13). The flanks are weakly convex and the venter narrowly rounded. Adulthood is indicated by septal approximation and egression of the body chamber. The septal suture (Text-fig. 12B) differs slightly in the somewhat higher E/L saddle.

Remarks.—Our macroconch is nearly identical with the syntypes of *P. zitteli* Burckhardt from the Tithonian of Argentina and almost certainly conspecific. A much larger specimen from Argentina, apparently with body chamber, was reported by Krantz (1928). Most of Imlay's (1942) *P. cf. P. zitteli* from Cuba, on the other hand, are identical with our probable microconchs. His collection, however, also contained a larger specimen (*loc. cit.* pl. 4, figs. 1-3) which, because of its somewhat wider umbilicus he compared with, among others, *P. subrasile* (Burckhardt) (1906). *P. subrasile* is apparently based upon a single, poorly preserved specimen which, except for the slightly greater evolution, is nearly identical to our and Imlay's microconchs. The scatter of umbilical width versus diameter, for the better preserved specimens among our material, along with those of Burckhardt, Imlay and Krantz (Text-fig. 13) indicates that (i) there is considerable variation within *P. zitteli*, (ii) *P. subrasile* and *P. aff. P. subrasile* can easily be accommodated within the limits of this variation, (iii) the larger specimen in Imlay's Cuban collection probably is a macroconch of *P. zitteli* (measurements from his description and figures).

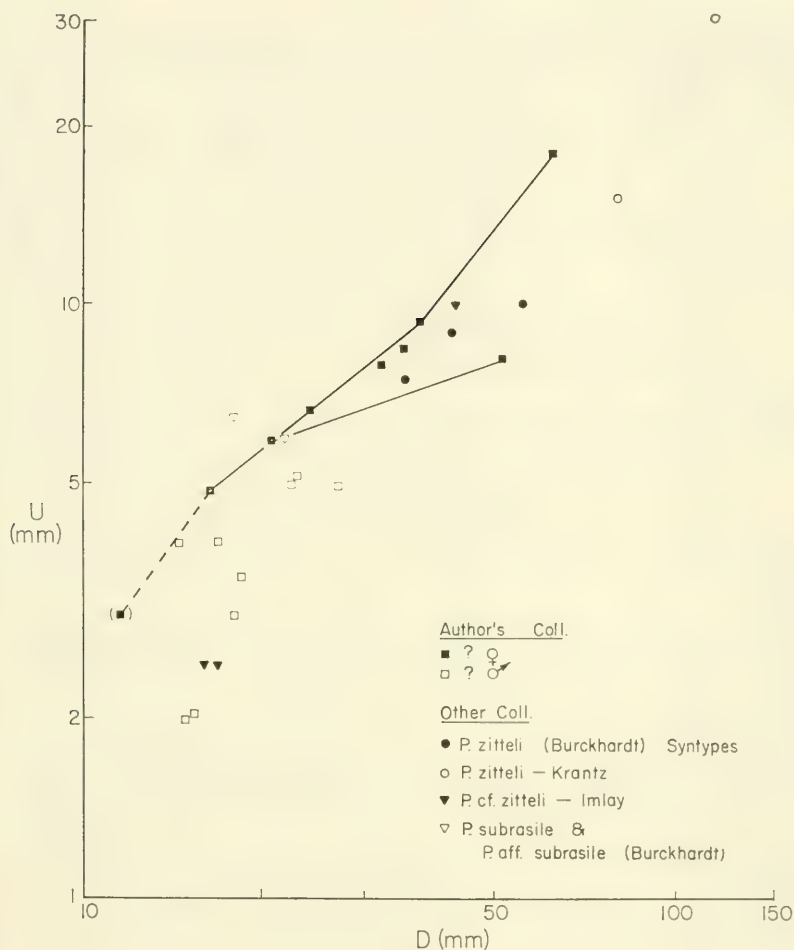
It is suggested here that *P. subrasile* (Burckhardt) is the microconch (δ) of the better known species *P. zitteli* (Burckhardt).

Occurrence.—Virgatosphinctinae beds, upper part of El Pastor Member, La Caja Formation, Sierra Catorce.

Age.—Upper part of Lower Tithonian.

Measurements (types and figured specimens only). —

	D	U	U/D	H	W	H/W
Holotype (? ♀)	55.0	10.0	0.81	29.0	15.0	1.93
	42.0	9.0	0.21	21.5	15.0	1.43
	35.0	7.5	0.21	18.0	11.0	1.63
" <i>N. subrasilis</i> " (? ♂)	18.0	6.5	0.36	8.0	7.0	1.14
holotype						
" <i>N. aff. subrasilis</i> "	23.5	6.0	0.25	11.0	6.0	1.83
of Burckhardt, 1906 (? ♂)						
<i>P. zitteli</i> of Krantz,	117.0	30.5	0.26	50.0	30.0	1.66
1928, ♀						
	79.0	15.0	0.19	38.0	22.5	1.68



Text-fig. 13. — Scatter diagram of umbilical width (U) *vs.* diameter (D) for *Pseudolissoceras zitteli* (Burckhardt), macroconchs [♀] + probable microconch [? ♂] from North America and South America. Inner whorls of only two better preserved macroconchs are plotted (approximate data in parenthesis and with dashed line). *P. subrasile* (Burckhardt) and *P. aff. subrasile* fall within the range of variation of *P. zitteli*.

P. cf. P. zitteli

of Imlay, 1939 (? ♀ + ♂)

Pl. 4, figs. 1-3	c.42.5	c.10.0	0.23	17.0	8.5	2.0
Pl. 4, figs. 7-8	17.0	2.5	0.14	9.0	5.0	1.8
Pl. 4, figs. 11-12	16.0	2.5	0.15	8.0	6.0	1.33
McM - J 1509/333 ♀	62.0	18.0	0.29	23.5	14.5	1.62
	37.0	9.3	0.25	11.0	6.3	1.74
	24.0	6.7	0.27	6.0	4.7	1.27
	16.5	4.9	0.29	—	—	—
	c.11.5	c.3.4	0.29	—	—	—
- J 1516/10 ♂	18.0	3.0	0.16	9.0	7.0	1.28
- J 1526/63 ♂	17.0	3.5	0.20	8.0	5.7	1.40

Genus "**PARAGLOCHICERAS**" Collignon, 1960

Type species: ? (Not designated).

"Paraglochiceras" *catorcense* (Aguilera), 1895

Pl. 26, fig. 8

1895. *Haploceras catorcensis* Aguilera in Castillo and Aguilera, Com. Geol. México, Bol. 1, p. 21, pl. VII, fig. 5.

Material. — The holotype only, a small well-preserved mold of phragmocone with impressed remains of body chamber (UNAM 27).

Description. — The shell is moderately evolute, discoidal, with a high rectangular whorl section. The flanks are weakly convex and the venter is evenly rounded. The umbilicus is moderately deep with steep umbilical wall of moderate height (≤ 1 mm). The inner whorls are smooth. The last half of the exposed outer whorl carries evenly spaced falcoid ribs which are extremely faint on the inner half of the flanks, becoming more prominent on the outer flank. Ribs from opposite flanks appear to meet at the venter in the form of blunt chevrons. A lateral groove is absent presumably because the specimen is an internal mold.

Remarks. — The genus "*Paraglochiceras*" was introduced by Collignon (1960, pls. 145-146) in plate descriptions only, without diagnosis or designation of a type species. All seven species from the Middle Tithonian of Madagascar included by Collignon are distinguished from *Hildoglochiceras* Spath by the more inflated whorl section and the absence of a lateral groove.

This species is placed in "*Paraglochiceras*" because of the apparent absence of a lateral groove and the inflation of the whorls. *Hildoglochiceras grossicostatum* Imlay (1939, p. 27, pl. 2, figs. 5-11;

pl. 3, figs. 1-7, 9-11) from the La Casita beds of Sierra de Parras, Coahuila, differs by being more involute, having more prominent and persistent ribs, and a keeled venter. The keel is absent in *H. inflatum* Imlay (1939, p. 29, pl. 4, figs. 1-5) also from the same beds in Northern Mexico. However *H. inflatum* has a lateral groove and faint striae which are anteriorly convex in the groove, but apicad convex both above and below the groove. Incidentally, the ornament of Aguilera's species is reminiscent of the Middle Bajocian *Toxamblyites* Buckman.

Occurrence. — Aguilera (in Castillo and Aguilera, 1895, p. 21) reported this species from the "Los Alamitos Beds" of "Alamitos, Mineral de Catorce San Luis Potosi", along with many perisphinctid "species" described by him. The probable source was the Virgato-sphinctinae beds of Los Alamitos (Loc. 23 of this work) where the listed perisphinctids are now known to occur.

Age. — Upper part of Lower Tithonian.

Measurements. —

	D	U	U/D	H	W	H/W
Holotype	21.0	4.5	0.21	10.0	8.0	1.25
	17.3	3.5	0.20	8.2	6.4	1.28

Cf. "*Paraglochiceras*" sp. indet.

Pl. 26, fig. 6

Material. — Two specimens from loc. 23A (McM - J 1505/185, 192); two from loc. 23B (McM - J 1506/78, 209). All are somewhat corroded and incomplete internal molds.

Description. — The shell is of medium size, planulate, and involute with elliptical whorl section. The umbilicus is narrow with steep slope, the flanks are weakly convex, and the venter is narrowly rounded. The earlier part of the outer whorl is smooth; the latter part carries distant, prominent, posteriorly convex ribs on the outer half of the flank.

Remarks. — The specimens are assigned to "*Paraglochiceras*" rather than *Glochiceras* Hyatt on the basis of the more evolute coiling and the prominent ribs. The absence of a spiral groove, the blunt venter, and the highly inflated whorls are typical of "*Paraglochiceras*" (see under "*P.* catorcense"). There is good resemblance

to "*P. aff. propinquum* Waagen" of Collignon (1960, pl. 146, fig. 578) from the Tithonian of Madagascar.

Occurrence. — Virgatosphinctinae beds, upper part of El Pastor Member, La Caja Formation, Sierra Catorce.

Age. — Upper part of Lower Tithonian.

Measurements. —

	D	U	U/D	H	W	H/W
McM - J 1505/185	—	—	—	16.0	10.5	1.52
- J 1505/192	33.0	6.5	0.19	15.0	9.5	1.57
- J 1506/78	40.0	7.0	0.17	21.0	12.0	1.75
- J 1506/209	31.0	6.0	0.19	15.0	9.5	1.57

Family **OPPELIIDAE** Bonarelli, 1894

Subfamily **MAZAPILITINAE** Spath, 1928

Genus **MAZAPILITES** Burckhardt, 1919

Type species: *M. symonensis* Burckhardt, 1919 (SD Roman, 1938).

Mazapilites mexicanus (Aguilera), 1895

Pl. 26, fig. 7

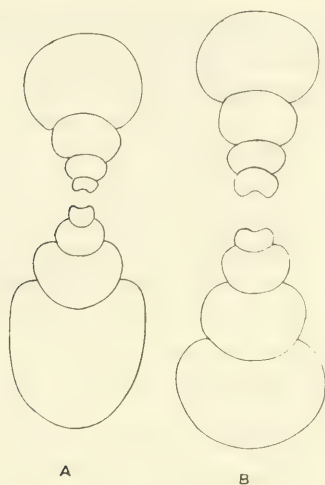
1895. *Pulchellia mexicana* Aguilera, in Castillo and Aguilera, Com. Geol. México, Bol. 1, p. 35, pl. VI, fig. 9, pl. VII, fig. 1.

1919. *Mazapilites mexicanus* (Aguilera), Burckhardt, Inst. Geol. México, Bol. 33, p. 6, pl. III, figs. 1-3.

Material. — Three specimens, all internal molds: two from loc. 23B (McM - J 1506/380, 381) of which the first is more than one-half of a large phragmocone, and the second a septate fragment; one *ex situ* from Los Alamos (McM - J 1509/331).

Description. — The shell is typically oxycone, highly involute with an extremely narrow umbilicus and depressed inner flanks. The whorl overlap of the outermost phragmocone whorl is about 30%. The cross section of the inner whorls is compressed elliptical, while the outer whorls are subtriangular with depressed inner flanks, maximum width at about one-third height and narrowly rounded venter. The umbilical slope is sharply rounded.

The prominent ribs are slightly curved arising near the umbilical shoulder with forward inclination and curving gently to become rectiradiate. Most primaries branch into two equally prom-



Text-fig. 14. — A Cross section of *Aulacosphinctoides lauri* (Aguilera), phragmocone, McM - J 1509/23, $\times 1$. B. Cross section of *Subdichotomoceras*, n. sp. aff. *S. inversum* Spath, macroconch [♀] phragmocone, McM - J 1506/17, $\times 0.5$.

inent secondaries at $2/3$ whorl height. Intercalatories are also common. The secondaries continue prominently across the narrow venter. The ribs become blunt toward the end of the phragmocone.

Remarks. — Because our collection of several thousand ammonites from Sierra Catorce contains only three specimens of *Mazapilites*, this genus appears to be extremely rare in this area. None of the syntypes of *M. mexicanus* could be found among the type collections in Mexico. Fortunately, however the plastotype of one of Aguilera's syntypes (1895, pl. VII, fig. 1) is available at the United States National Museum (USNM 103295). *M. mexicanus* resembles the type species *M. symonensis* Burckhardt (1919-21, p. 4, pl. 1, fig. 4, 5) but is somewhat more compressed and has a more narrow venter. *M. crassicosatus* Burckhardt (1919-21, p. 7, pl. 2, figs. 1-4, 6, 7, 10) is much more coarsely ribbed and, like most other ill-defined species of *Mazapilites* described by Burckhardt, has a broader venter.

Occurrence. — Virgatosphinctinae beds, upper part of El Pastor Member, La Caja Formation, Sierra Catorce.

Age. — Upper Lower Tithonian.

Measurements. —

	D	U	U/D	H	W	H/W	P/½ wh.
Syntype, plaster cast, (USNM 103295)	78.0	—	—	58.0	30.0	1.93	10
McM - J 1506/380	82.0	12.0	0.14	48.0	21.0	2.28	10
- J 1506/381	—	—	—	38.0	15.0	2.53	—
- J 1509/331	—	—	—	50.0	23.0	2.17	—

Superfamily **PERISPINCTACEAE** Steinmann, 1890

Family **PERISPINCTIDAE** Steinman, 1890

Subfamily **ATAXIOCERATINAE** Buckman, 1921

Genus **IDOCERAS** Burckhardt, 1906

Type species: *Ammonites planula* Zieten, 1830 (SD Roman, 1938).

Idoceras is known from northern Mexico, outside of the area of this study, in great variety and profusion. Burckhardt (1906, 1912) named 32 alleged species to which 6 were added by Imlay (1939). In the Sierra Catorce, poorly preserved *Idoceras* occurs approximately 3 m above the base of the El Pastor Member of the La Caja Formation. The collection from El Pastor (loc. 40A) includes about 40 fragments, most of which are either broken or distorted beyond recognition. Because of the imperfect preservation no taxonomic revision is attempted here. However, since *Idoceras* is an important faunal element of the Mexican Jurassic, the following better preserved specimens are tentatively identified.

Idoceras cf. I. inflatum Burckhardt, 1906

Pl. 27, fig. 1

?1906. *Idoceras inflatum* Burckhardt, Inst. Geol. México, Bol. 23, p. 65, pl. VIII, fig. 5-8.

Material. — One small septate fragment from loc. 40A (McM - J 1530/2).

Description. — The small shell (D = 32 mm) is planulate and evolute with wide umbilicus. The whorl section is subovate, almost

as high as wide, with low umbilical wall and rounded shoulder. The shell bears moderately strong prorsiradiate primaries, most of which bifurcate at approximately $2/3$ whorl height; simple ribs are rare. The secondaries are projected and continuous across the venter with slight weakening in the mid-ventral area comprising an obtuse angle. Two prominent prorsiradiate constrictions are present. The rib preceding the strongest constriction is branched virgatotome.

Remarks. — Our specimen closely resembles *I. inflatum* Burckhardt (1906) in size, costation, and constrictions. *I. sautieri* Burckhardt (1912, p. 103, pl. XXV, figs. 1-4) and a series of similar evolute "species" of Burckhardt appear to be close to *I. inflatum* but are probably more compressed, while *I. humboldti* Burckhardt (1906, p. 44, pl. IX, figs. 5-8) is also more densely ribbed.

Occurrence. — Lower part of El Pastor Member, La Caja Formation, Sierra Catorce.

Age. — Kimmeridgian.

Measurements. —

	D	U	U/D	H	W	H/W	P/½	Wh.
McM - J 1530/2	c.32.00	c.12.0	0.37	10.0	10.5	0.95		17

***Idoceras* cf. *I. mutabile* Burckhardt, 1912**

?1912. *Idoceras mutabile* Burckhardt, Inst. Geol. México, Bol. 29, p. 123, pl. XXXII, figs. 1-5.

Material. — Seven whorl fragments from loc. 40A (McM - J 1530/3, 6, 7, 8, 11, 18, 19).

Description. — The shell is discoidal and evolute. The whorl section is compressed subtriangular with rounded venter. The flanks bear some blunt distant primaries which have been somewhat weathered on our specimens. Most primaries bifurcate on the outer flanks, some ribs are simple and intercalatories are rare. On the shoulders the ribs become stronger and projected. The mid-ventral area is smooth.

Remarks. — The poor preservation and fragmentary nature of the specimens does not allow any precise determination. A study of Imlay's Mexican collection at the University of Michigan by Verma showed that the ribbing of our specimens resembles that of *I. involutum* Imlay (1939, p. 37, p. 12, figs. 3, 4) from the *Idoceras*

beds of San Lazaro Canyon, Nuevo Leon. However, the whorl section of our form is more strongly triangular as in *I. mutabile*.

Occurrence. — Lower part of El Pastor Member, La Caja Formation, Sierra Catorce.

Age. — Kimmeridgian.

Measurements (best preserved specimen). —

	D	H	W	H/W
McM - J 1530/3	—	35.0	19.0	1.84

Idoceras ex. gr. ***I. neohispanicum*** Burckhardt, 1912 Pl. 31, fig. 3

1912. *Idoceras neohispanicum* Burckhardt, Inst. Geol. México, Bol. 29, p. 112, pl. XXIV, figs. 1-4, 6, 8.

Material. — Nine poorly preserved fragmentary specimens, impressions or highly distorted internal molds, from loc. 40A (McM - J 1530/4, 5, 9, 12, 13, 14, 17).

Description. — The specimens cannot be identified specifically; however, whorl section and costation are clearly diagnostic of *Idoceras*, of the group of *I. neohispanicum* Burckhardt (1912, p. 111, pl. XXIX, figs. 1-3, 4, 6, 8). The shell is discoidal, compressed and fairly involute, probably with steep umbilical slope. The ribbing is dense. The primaries originate at the umbilical seam and are prorsiradiate. Most ribs bifurcate at the mid-flank; simple and intercalatory ribs are common. Near the ventral margin, the ribs are swollen before being interrupted at mid-venter.

Remarks. — Burckhardt (1912) described a number of apparently intimately affiliated "species" with similar rather evolute coiling and prominent ribbing from San Pedro del Gallo, which are here tentatively referred to as "group of *I. neohispanicum*".

Occurrence. — Lower part of El Pastor Member, La Caja Formation, Sierra Catorce.

Age. — Kimmeridgian.

Measurements. — Because of extreme distortion, none of the specimens was measured.

Subfamily **VIRGATOSPHINCTINAE** Spath, 1923

Genus **AULACOSPHINCTOIDES** Spath, 1923

Type species: *Aulacosphinctes infundibulus* Uhlig, 1910.

Aulacosphinctoides lauri (Aguilera), 1895 [♀ + ? ♂]
Pl. 27, figs. 2-5; Text-fig. 14A

1895. *Perisphinctes lauri* Aguilera in Castillo and Aguilera, Com. Geol. México, Bol. 1, p. 26, pl. XVI, fig. 2 [lectotype, here designated], fig. 3.
1895. *Perisphinctes transitorius* ? Oppel, *ibid.*, p. 30, pl. XXI, fig. 5.
1906. *Perisphinctes aguilar* Burckhardt, Inst. Geol. México, Bol. 23, p. 110, pl. XXVII, figs. 6-9.

Material.—Eighteen satisfactorily preserved specimens: two from loc. 23A (McM - J 1505/7, 8); one from loc. 23B (McM - J 1506/18); nine *ex situ* from Los Alamitos (McM - J 1509/20-25, 27-29); one from loc. 40C (McM - J 1528/43); three from loc. 40E (McM - J 1529/50, 56, 96); two from loc. 40F (McM - J 1530/54, 127). Most specimens appear to be macroconchs, while McM - J 1509/23, 24 are probably microconchs.

In addition the collection contains several dozen ill-preserved specimens from the Virgatosphinctinae beds of Los Alamitos and El Pastor. Most of these, however, are either strongly distorted or covered with matrix which is firmly cemented to the fossil. All attempts to dislodge the matrix (air abrasion, acid treatment, vibro-tool, pneumatic drill, alternate heating and cooling) resulted only in disintegration or corrosion of the specimens. This is true for many of the specimens of Perisphinctidae, Haploceratidae, Aspidoceratidae, and Oppeliidae collected from the upper part of El Pastor Member of the La Caja Formation (Virgatosphinctinae beds) exposed in locs. 23A, 23B, 24 (Los Alamitos) and locs. 40C, 40D, 40E and 40F (El Pastor). These beds in the studied outcrops are packed with imperfectly preserved ammonites and bivalves. Although only a small percentage of the total number of specimens of this species are recorded here, the description is true for the total available sample.

Description.—The shell is planulate, somewhat evolute (about 15-20% overlap). The whorl section is depressed to subquadrate (Text-fig. 14A) in the inner whorls, while the outer whorls are subrectangular and higher than wide. The umbilicus is fairly wide and deep with steep umbilical walls. The flanks and the venter are evenly rounded, continuous. The inner whorls have dense, sharp rectiradiate ribs, which do not show any evidence of bifurcation before the line of involution but presumably are branched on the upper part of the flanks. On the outer whorls, the ribs con-

tinue to remain sharp but are marked prorsiradiate. Most ribs bifurcate, somewhat irregularly at about $2/3$ whorl height. Simple ribs are fairly common but intercalatories are absent. The secondaries are anteriorly convex on the venter becoming more narrowly rounded with growth. At least two specimens (McM - J 1509/23, 24) are probably microconchs. They appear to be adult, resemble the inner whorls of the macroconchs, and occur together with them.

Remarks.—Of the two syntypes of "*P.*" *lauri*, the lectotype (here designated: Castillo and Aguilera, 1895, pl. XVI, fig. 2) is most probably a macroconch while the paralectotype (*op. cit.*, pl. XVI, fig. 3) is smaller and may be a microconch. Both specimens have been prepared with permission from Instituto de Geología, Universidad Autónoma de México, and are refigured (Pl. 27, figs. 3-4). A small whorl fragment identified by Aguilera as "*P.*" *transitorius* ? Oppel" also appears to belong to *A. lauri*.

Two other species described by Aguilera deserve mention here. These are "*Perisphinctes*" *mazapilensis* (in Castillo and Aguilera, 1895, p. 23, pl. X) and "*P. balderus* Oppel" (*op. cit.*, p. 24, pl. XI, fig. 1). The material of these species is not available in Mexico, but the lateral views illustrated by Aguilera (*loc. cit.*) show ribbing similar to *A. lauri*. In the case of "*P.*" *mazapilensis*, the ribbing is considerably coarser and more sigmoidal. It appears that both specimens could be assigned to *Aulacosphinctoides*. "*Perisphinctes felixi* Aguilera" described by Cragin from Texas (1905, p. 106, pl. XXIII, fig. 2) was examined by Verma at the U.S. National Museum. This specimen is coarsely ribbed and has no affinity with the types of Aguilera. "*P.*" *aguilari* Burckhardt (1906) closely resembles *A. lauri* and related species in whorl shape, coiling, and costation and is, therefore, synonymized.

Occurrence.—Virgatosphinctinae beds, upper part of El Pastor Member, La Caja Formation, Sierra Catorce.

Age.—Upper part of Lower Tithonian.

Measurements (types and better preserved specimens only). —

	D	U	U/D	H	W	H/W	P/½ Wh.
Lectotype	75.0	24.7	0.33	36.0	24.7	1.45	27
Paralectotype	55.0	16.0	0.29	22.0	21.0	1.04	25
McM - J 1505/7	66.5	28.0	0.42	22.0	27.0	0.81	27
- J 1506/18	61.0	25.0	0.40	20.0	25.0	0.97	27
- J 1509/20	59.5	23.5	0.39	21.5	21.0	1.02	—
- J 1509/23	c.50.0	c.18.0	0.36	18.5	18.0	1.02	25
- J 1509/24	60.0	26.0	0.43	19.0	20.5	0.92	24
- J 1509/25	55.0	20.0	0.36	18.0	20.0	0.90	—
- J 1509/27	57.0	21.0	0.36	20.0	21.0	0.95	24
- J 1509/28	75.0	30.0	0.40	25.0	29.0	0.86	30

***Aulacosphinctoides potosinus* (Aguilera), 1895**

Pl. 28, figs. 1-2

1895. *Perisphinctes potosinus* Aguilera in Castillo and Aguilera, Com. Geol. México, Bol. 1, p. 31, pl. XVII, fig. 1 [lectotype here designated]; *not* pl. XXIV, figs. 2 [= *Pseudoinvoluticeras*].

1895. *Perisphinctes felixi* Aguilera, *ibid.*, p. 25, pl. XVI, fig. 1.

Material. — The lectotype; a somewhat distorted apparently complete specimen with slightly crushed body chamber, from the “Los Alamitos Beds” of “Rancho Alamitos” (UNAM 11). The holotype of “*P. felixi*”; a moderately well-preserved phragmocone from the same beds and locality (UNAM 22).

Description. — The shell is planulate and evolute with sub-circular whorl section. The flanks are weakly convex and the venter broadly rounded. The wide umbilicus is moderately deep with high umbilical wall and rounded umbilical shoulder. The inner as well as the outer whorls are covered with moderately dense ribs which are somewhat rursiradiate on the umbilical wall, nearly reciradiate over most of the flanks, and slightly projected. Branching of the primaries occurs at about midflank. In the earlier whorls almost all ribs bifurcate while later, trifurcation becomes more common. Occasionally, bifurcation takes place twice, a single primary giving rise to four secondaries. All the secondaries cross the venter somewhat convexly, without any interruption or diminution of strength. A few irregularly spaced constrictions are present.

Remarks. — Of the two syntypes described by Aguilera (in Castillo and Aguilera, 1895) under “*Perisphinctes potosinus*”, the smaller one (pl. XXIV, fig. 2), because of the denser ribbing, greater involution, and the high vertical umbilical wall, is here placed in the genus *Pseudoinvoluticeras*. The larger coarsely ribbed

syntype figured by Aguilera (*op. cit.*, pl. XVII, fig. 1) is probably a macroconch and is designated here as the lectotype. "*Perisphinctes felixi*" Aguilera, is nearly identical in shell dimensions and ribbing and is therefore considered conspecific. The lectotype of *A. potosinus* and the holotype of "*P. felixi*" are both refigured here after preparation from the matrix (Pl. 28, figs. 1-2). *A. potosinus* differs from *A. lauri* (Aguilera) in the coarser ribbing; it is also more evolute and has a more rounded whorl section with less developed umbilical angle.

Occurrence. — *A. potosinus* was reported by Aguilera (*in* Castillo and Aguilera, 1895) from "Rancho Alamitos, Sierra de Catorce, San Luis Potosi" and *P. felixi* from "Arroyo de Alamitos, Rancho Los Alamitos, Sierra de Catorce, San Luis Potosi". Both the forms occur in the so called "Los Alamitos Beds" of Aguilera (*op. cit.*). The matrix is similar to that of the fossils from the Virgatosphinctinae beds of Los Alamitos (Loc. 23 of this work). It is, therefore, concluded that *A. potosinus* occurs in the Virgatosphinctinae beds, upper part of El Pastor Member, La Caja Formation, Sierra Catorce.

Age. — Upper part of Lower Tithonian.

Measurements. —

	D	U	U/D	H	W	H/W	P/½ wh.	S/½ wh.
Lectotype	c.109.0	c.47.0	0.43	c.36.0	c.30.0	1.20	21	53
(phrag. + ? body ch.)								
	c.110.0	c.50.0	0.45	c.40.0	c.27.0	1.48	23	55
" <i>P. felixi</i> "	75.0	29.5	0.39	26.0	28.0	0.92	21	26
Aguilera								
	64.0	28.0	0.43	22.0	25.0	0.88	22	42

Genus **PSEUDOINVOLUTICERAS** Spath, 1925

Type species: *P. somalicum* Spath, 1925.

Pseudoinvoluticeras cf. *P. mozambicum* Collignon, 1960 Pl. 29, fig. 1

1895. *Perisphinctes potosinus* Aguilera *in* Castillo and Aguilera, Com. Geol. México, Bol. 1, p. 31, pl. XXIV, fig. 2; *not* pl. XVII, fig. 1 [= *Aulacosphinctoides potosinus*].

?1960. *Pseudoinvoluticeras mozambicum* Collignon, Atl. foss. caract. Madagascar, vol. VI, pl. CLIX, fig. 631.

Material. — The paralectotype of "*P. potosinus*" Aguilera (UNAM 12), a well-preserved phragmocone from "Rancho Alamitos, Sierra de Catorce, San Luis Potosí, Mexico".

Description.—The shell is relatively involute and almost discoidal with subtrapezoidal whorl section. The flattish flanks converge from the umbilical shoulders to the shoulders of the rounded venter. The umbilicus is fairly deep with high vertical umbilical wall. The shell is covered with fine dense ribbing which on the outer whorl is at first predominantly biplicate, and later triplicate or virgatotome. The ribs are rursiradiate at the umbilical wall, curve at the umbilical shoulder to become prorsiradiate over the flanks, and cross the venter without projection or interruption.

Remarks.—This is the second of the two syntypes of "*Perisphinctes*" *potosinus* figured by Aguilera (1895); the first one is chosen here as lectotype of *Aulacosphinctoides potosinus*. In shell shape and ornament, our specimen closely resembles *P. mozambicum* Collignon (1960), but differs in being smaller and having somewhat more numerous primaries. *P. somalicum* Spath, the type species, is more strongly involute and has typically fasciculate ribbing.

Occurrence.—"Los Alamitos Beds", Sierra Catorce.

Age.—Upper part of Lower Tithonian.

Measurements.—

		D	U	U/D	H	W	H/W	P/½ wh.
UNAM	12	83.0	29.0	0.35	33.2	29.0	1.14	25

Genus **SUBDICHOTOMOCERAS** Spath, 1925

Type species: *Subdichotomoceras lamplughi* Spath, 1925.

Subdichotomoceras n. sp. aff. **S. inversum** Spath, 1931 [♀ + ♂]
Pl. 30, figs. 1-2; Pl. 31, figs. 1-2; Text-fig. 14B

?1895. *Perisphinctes colubrinus* (Reinecke), Aguilera in Castillo and Aguilera, Cm. Geol. México, Bol. 1, p. 23. [non. "*Perisphinctes* cf. *colubrinus* (Reinecke)", *ibid.*, p. 22, pl. VII, fig. 8].

Material.—Thirty-four moderately preserved specimens: eighteen from loc. 23B (McM - J 1506/14, 15, 17, 32, 43, 94, 154, 156, 158, 160, 162, 163, 250, 376-380); five from loc. 23A (McM - J 1505/6, 38, 105, 119, 127); six *ex situ* from Los Alamitos (McM - J 1509/11-14, 43, 210); four from loc. 40E (McM - J 1529/31, 54, 60, 63); one from loc. 40F (McM J 1530/2, 110). Of these, specimens J 1506/17 and 379 are (?) macroconchs, the latter being a nearly complete shell with missing innermost whorls; J 1509/12 and 14 are (?) microconchs. Also a number of fragments.

Description. — The shell is planulate, rather evolute, almost serpenticone with whorl overlap of 10-15%. The whorl section between the ribs (Text-fig. 14B) is depressed subcircular. The inner whorls have coarse evenly spaced rectiradiate ribs which originate at the umbilical seam, with gently concave intercostal spaces. On the outer whorls, the ribs continue to be prominent and rectiradiate, with some primaries curving on the umbilical wall. Biplication occurs uniformly at about 2/3 whorl height and the regular secondaries continue uninterrupted over the venter. Some of the smaller specimens in the collection are identical to the inner whorls of the larger specimens; they are adult according to the septal approximation and the egression of the body chamber, and are most probably microconchs. Parts of the septal suture are visible in some specimens but attempts to prepare a complete suture were unsuccessful.

Remarks. — In whorl shape and coiling as well as in the prominence of the ribs, our specimens resemble *S. inversum* Spath (1931, p. 521, pl. LXXXIV, fig. 5, pl. 85, fig. 4) from the Middle Katrol Beds of Kachh; *S. inversum* differs in the somewhat shorter primaries. Aguilera recorded but did not illustrate "*Perisphinctes colubrinus* (Reinecke)" from Sierra Catorce which appears to be lost; the specimen figured as "*P. cf. colubrinus* (Reinecke)" is more serpenticone and has coarser ribbing than true *Aulacosphinctoides colubrinus*. Many of the perisphinctid species described by Burckhardt under *Aulacosphinctes*, e.g. *Perisphinctes* (*Aulacosphinctes*) *subleicheri* (1919-21, pl. XIII, figs. 1-5), *P. (A.) bangei* (*op. cit.*, pl. IX, figs. 5-9), and *P. (A.) symonensis* (*op. cit.*, pl. XI, figs. 4-7), differ from *Aulacosphinctoides s.s.* by the presence of marked constrictions. They should, therefore, be transferred to either *A. (Torquatisphinctes)* or *Dichotomosphinctes* depending on the whorl section and the frequency or scarcity of simple ribs. Of the Argentine species, *Aulacosphinctes azulensis* Leanza (1945, p. 20, pl. I, figs. 6, 7) and "*A. mangaensis* Steuer" of Leanza (1945, pl. III, figs. 1, 2) appear to belong to a single species which closely resembles *Aulacosphinctoides colubrinus*.

Occurrence. — Virgatosphinctinae beds, upper part of El Pastor Member, La Caja Formation, Sierra Catorce.

Age. — Upper part of Lower Tithonian.

Measurements (better preserved specimens). —

	D	U	U/D	H	W	H/W	P
McM - J 1506/379 ♀	140.0	69.0	0.49	39.0	42.0	0.82	50/wh.
- J 1506/17 ♀	108.0	53.0	0.49	28.0	36.0	0.77	20/½ wh.
- J 1509/12 ♂	51.0	21.0	0.41	16.0	20.0	0.80	37/wh.
- J 1509/13 ♀	60.0	30.0	0.50	16.0	20.0	0.80	20/½ wh.
- J 1509/14 ♂	70.0	34.0	0.48	21.0	22.0	0.95	38/wh.

Genus **VIRGATOSPHINCTES** Uhlig, 1910

Type species: *Virgatosphinctes broilii* Uhlig (SD R. Douville, 1912).

? **Virgatosphinctes fresnosensis** Imlay, 1942

Pl. 31, fig. 4

?1943. *Subplanites*, *fresnosensis* Imlay, Jour. Paleont., vol. 17, p. 532, pl. 88, figs. 1-4, pl. 89, fig. 5.

Material. — One fragment of a large phragmocone whorl with segment of inner whorl, poorly preserved, from loc. 40C (McM - J 1528/47).

Description. — The whorl section is depressed; the flanks are broadly convex and the venter evenly rounded. The primary ribs are long, prominent and rectiradiate; near the ventral shoulder, they bifurcate into prominent secondaries, crossing straight over the venter. The attached part of the inner whorl has similar coarse primary ribs.

Remarks. — Our fragment closely resembles the mature part of the phragmocone of "*Subplanites*" *fresnosensis* Imlay (1943) in whorl section and costation. A part of the septal suture is visible near the umbilical shoulder and is similar to that given by Imlay (*loc. cit.*).

Occurrence. — *Virgatosphinctinae* beds, upper part of El Pastor Member, La Caja Formation, Sierra Catorce.

Age. — Upper part of Lower Tithonian.

Measurements. —

	D	H	W	H/W	P
McM - J 1528/47	(c.250.0)	72	95	0.85	5

Virgatosphinctes sanchezi Verma and Westermann, n. sp. [○ + ? ♀]
Pl. 32; Pl. 33; Pl. 34, fig. 2; Text-fig. 15

?1906. *Virgatites* sp. ind., Burckhardt, Inst. Geol. México, Bol. 33, p. 39, pl. XIV, figs. 1-3.

?1939. *Subplanites* ? sp., Imlay, Geol. Soc. America, Bull. 50, p. 36, pl. 9, fig. 13 only.

Holotype. — Specimen McM J 1528/2; a giant complete macroconch, well preserved but distorted, with body chamber; largest of all the specimens from Sierra Catorce. One side and one venter well exposed.

Paratype. — Specimen McM - J 1529/98 from loc. 40E; incomplete phragmocone and (?) body chamber, possibly a microconch, with well-preserved inner whorls.

Locus typicus. — Locality 40C, section exposed in stream cut near El Pastor, about 200 m east of Tierras Negras, Sierra Catorce.

Stratum typicum. — Virgatosphinctinae bed ("0"), about 27 m from base of section; upper part of El Pastor Member, La Caja Formation.

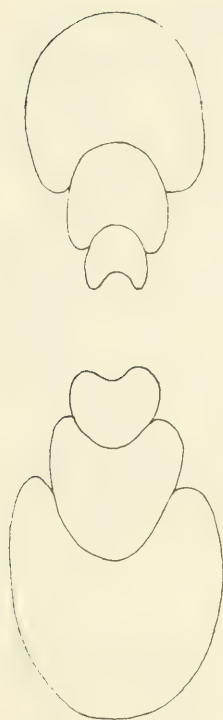
Derivatio nominis. — After Mr. Evaristo Sánchez of Real de Catorce, who was field assistant, host, and interpreter.

Age. — Upper part of Lower Tithonian.

Diagnosis. — A giant macroconch *Virgatosphinctes* with subquadrate whorl section. Inner whorls with sharp dense ribbing, biplicate, triplicate or virgatotome; middle and outer whorls with distant prominent primaries and obsolescent secondaries.

Material. — In addition to the holotype and the paratype, one from loc. 23A (McM - J 1505/151); three from 23B (McM - J 1506/289, 382, 383); four from loc. 40C (McM - J 1528/1, 39, 41, 42); and one *ex situ* from El Alamarito (McM - J 1531/1). Most specimens are phragmocones or fragments. J 1528/41 is now at UNAM.

Description. — The shell is giant, the holotype having a diameter of about 540 mm, with rounded subquadrate whorl section (Text-fig. 15). The test is thick. The overlap between the whorls is about 25%. The umbilicus is wide, fairly deep with steep rounded umbilical slope. The inner whorls have sharp dense primaries, which are rursiradiate on the umbilical slope and become prorsiradiate on the shoulder and flanks. At about 120 mm diameter the primaries become blunt, prominent and much more distant. On the inner whorls almost all the ribs bifurcate or trifurcate at about 2/3 whorl height, while simple and truly virgatotome ribs are rare. The secondaries are regular and continue uninterrupted across the venter. On the middle and outer whorls, the secondaries are obsolescent; the body chamber has a smooth venter. Several weak constrictions are present. The aperture, partly visible on the



Text-fig. 15. — Cross section through the phragmocone of *Virgatosphinctes sanchezi*, n. sp., macroconch (♀), McM - J 1531/1, $\times 0.2$.

holotype, has a simple weakly sinuous peristome. The small paratype ($D = 175$ mm), apparently also adult, is only approximately one-third the size of the holotype. There is otherwise close resemblance particularly in the inner whorls, with change to coarse lateral ribbing occurring at about 135 mm diameter (*vs.* 175 mm D). There appears to be a good possibility that, although also varicosate, the paratype represents the corresponding microconch. The septal suture (Pl. 37, fig. 2) has a deep E, an equally deep L and two suspensive and oblique umbilical lobes. The internal suture is preserved on specimen McM - J 1531/1 with a deep pointed I, a relatively thin I/U saddle, and strongly suspensive umbilical lobes.

Remarks. — Only a few specimens of *Virgatosphinctes* are known from Mexico. This species is unusually large and no species of such giant dimensions has been recorded, either from Mexico or South America. Indans (1954) recorded a variety of *virgatosphinct-*

tids from Argentina, some of which have affinities to the Indo-Malgache region. Several of her specimens, *e.g.* *V. inequicostatus* Indans, *V. cf. mexicanus* (Burckhardt), and *V. (Subplanites?) aff. pseudolictor* (Choffat), appear to resemble the inner whorls of *S. sanchezi*, but differ in the absence of the coarsely ribbed adult stage. Burckhardt (1906) described two specimens under "*Virgatites* sp. ind.", one of which (p. 39, pl. XLV, figs. 1-3) appears to be a fragment of a large specimen and is somewhat similar to *V. sanchezi*, except for the more prominent, bifurcating simple ribs. The middle whorls of our species seem to resemble ? *V. fresnosensis* Imlay (1943, p. 532, pl. 88, fig. 1-4, pl. 89, fig. 5); however, a study of the material at the U.S. National Museum by Verma indicated that Imlay's species has much coarser primaries and secondaries on the inner whorls. Imlay (1939) also reported a small shell and a larger fragment as "*Subplanites* ? sp." of which the larger fragment (1939, pl. 9, fig. 13) may be identical with our species.

Occurrence. — Virgatosphinctinae beds, upper part of El Pastor Member, La Caja Formation, Sierra Catorce.

Measurements. —

	D	U	U/D	H	W	H/W	P/½ wh.
Holotype (♀)	540.0	272.0	0.50	c.165.0	c.14.00	0.11	19
Paratype (? ♂)	175.0	76.0	0.43	60.0	65.0	0.92	16
McM - J 1505/151	—	—	—	61.0	69.0	0.88	—
- J 1506/289	—	—	—	51.0	58.0	0.87	—
- J 1506/382	c.295.0	c.150.0	0.50	c.75.0	c.76.0	0.98	—
- J 1506/383	c.320.0	c.190.0	0.59	c.70.0	c.85.0	0.82	c.15
- J 1528/41	c.149.0	c.65.0	0.43	c.49.0	c.53.0	0.92	c.26
- J 1528/42	192.0	80.0	0.41	61.1	69.9	0.88	—
- J 1531/1	196.0	83.0	0.42	62.0	61.0	0.10	—

Virgatosphinctes aff. *V. communis* Spath, 1931

Pl. 34, fig. 1

Material. — One giant phragmocone, somewhat distorted, large-ly with shell, from loc. 40C (McM - J 1528/11).

Description. — According to the size of the phragmocone (D = 300 mm), the complete shell was gigantic. The phragmocone is planulate, somewhat evolute, with subovate whorl section of the outer whorls. The steep umbilical wall rounds narrowly into the weakly convex converging flanks while the venter is well rounded. The inner whorls have dense sharp primary ribs which on the outer phragmocone whorl become blunt bullae-like, more distant and

shorter. The dense fine secondaries arise in bundles on the outer half of the flank and cross straight over the venter. Ribbing is sharp on the inner whorls but becomes very faint on the outermost whorl, so that the flanks of the mature phragmocone are almost smooth. The last septa are approximated, indicating the adult stage.

Remarks. — Our specimen resembles *V. communis* Spath (1931, p. 535, pl. 90, fig. 2 and pl. 155, fig. 4) from India and Madagascar (Collignon, 1960, pl. 155, fig. 622) in whorl shape, coiling, and probably diameter. However, *V. communis* differs in the more evolute, less inflated whorls. The apparent absence of bullate primaries on the Indo-Pacific form may be due to the incompleteness of the illustrated specimens; according to Spath (1931, p. 536) "a stage of almost perfect smoothness" marks the adult stage. The Mexican *V. cristobalensis* Imlay (1942, p. 1447, pl. 4, fig. 13) is smaller and, although similar in coiling, is reported to have constrictions on each whorl which cannot be seen on our specimen. *V. guadalupensis* Imlay (1943, p. 533, pl. 90, figs. 1-6) and *V. chihuahuensis* Imlay (1943, p. 534, pl. 91, figs. 2-5) are much more evolute than *V. communis*. *Virgatosphinctes* is common in the Lower Tithonian "Virgatosphinctes beds" of Neuquén Province, Argentina, from where several species were described particularly by Burckhardt (1900, 1903) and Weaver (1931) (*non* "*V.*" *leufuensis*, "*V.*" *patagoniensis*). Most of the Argentinian species are, however, more coarsely ribbed and more involute.

Occurrence. — Virgatosphinctinae beds, upper part of El Pastor Member, La Caja Formation, Sierra Catorce.

Age. — Upper part of Lower Tithonian.

Measurements. —

	D	U	U/D	H	W	H/W
McM - J 1528/11	300.0	100.0	0.33	120.0	112.0	1.07

Family **ASPIDOCERATIDAE** Zittel, 1895

Subfamily **ASPIDOCERATINAE** Zittel, 1895

Genus **ASPIDOCERAS** Zittel, 1868

Type species: *Ammonites rogoznicensis* Zeuschner, 1846.

Aspidoceras alamitocense Aguilera, 1895

Pl. 35, fig. 1

1895. *Aspidoceras alamotocensis* Aguilera in Castillo and Aguilera, Com. Geol. México, Bol. 1, p. 43, pl. XXIII [lectotype, here designated]; ? pl. XXII, fig. 6 [? ♂].
1905. *Aspidoceras alamitocensis* Aguilera, Cragin, U.S. Geol. Sur., Bull. 266, pl. 27, fig. 2.

Material. — Two large incomplete distorted phragmocones from loc. 40C (McM - J 1528/5, 6).

Description. — The diameter of the larger almost complete specimen is 210 mm. The whorls are highly inflated with depressed ovate or elliptical section. The umbilicus is fairly wide. On the flanks are two rows of prominent spinose tubercles which are radially elongated at the base but taper outwards. The largest tubercle is about 10 mm high. The inner row lies on the umbilical shoulder, with seven tubercles on the half whorl body chamber of the largest specimen; the outer row is at about mid-flank, with ten tubercles on the same half whorl. On the apical part of the body chamber, the inner and outer tubercles are placed in opposition on radial swellings, while they are later partly staggered. The outer tubercles are joined by blunt distant undulations passing over the venter.

Remarks. — The two syntypes are not among the collections in Mexico. However a plaster cast of the larger one, originally figured on plate XXIII and here designated as the lectotype, is available at the U.S. National Museum (USNM 10332). Our specimens are nearly identical to the lectotype. This species differs from other Mexican *Aspidoceras* by its larger diameter, the prominence and wide spacing of the tubercles, and the ridges on the venter. *A. euomphalum* Steuer (1897, pl. V, figs. 1-4) from Argentina differs by the smaller tubercles located lower on the flanks. *A. castitense* Imlay (1939, p. 32, pl. 5, fig. 7, pl. 6, fig. 11) from Sierra de Parras in Mexico is smaller, more evolute, and has fine radial striations.

Note. — In the original citation, the epithet appears to have been deliberately spelled with "c" instead of "s" in order to distinguish it from a berriasellid species derived from the same trivial name.

Occurrence. — Virgatosphinctinae beds, upper part of El Pastor Member, La Caja Formation, Sierra Catorce.

Age. — Upper part of Lower Tithonian.

Measurements. —

	D	U	U/D	H	W	H/W
Lectotype	146.0	45.0	0.30	67.0	95.0	0.70
McM - J 1528/5	210.0	c.60.0	0.28	90.0	110.0	0.81

Aspidoceras cf. *A. alamitocense* Aguilera, 1895

Pl. 35, fig. 2

?1895. *Aspidoceras alamitocensis* Aguilera in Castillo and Aguilera, Com. Geol. México, Bol. 1, p. 43, pl. XXII, fig. 6.

Material. — One small moderately preserved phragmocone, juvenile or incomplete, from Loc. 23B (McM - J 1506/384).

Description. — The shell is very small ($D = 40.0$ mm) with highly inflated, depressed semicircular whorl section and a moderately wide umbilicus. The flanks as well as the venter are sharply rounded. Two rows of tubercles occur on the flanks of which the outer is more prominent. The outermost septate whorl carries about 13 outer tubercles. The outer tubercles from opposite flanks are joined by prominent undulations which are slightly flexed anteriorly.

Remarks. — Our specimen appears to be nearly identical to the small syntype (paralectotype) of Aguilera (1895, pl. XXII, fig. 6). With only 40 mm diameter and in the absence of septal approximation, our phragmocone may be either the nucleus of a larger shell with unknown diameter ($\varnothing$ or δ) or an incomplete juvenile shell, identical or closely related to *A. alamitocense*.

Occurrence. — Virgatosphinctinae beds, upper part of El Pastor Member, La Caja Formation, Sierra Catorce.

Age. — Upper part of Lower Tithonian.

Measurements. —

	D	U	U/D	H	W	H/W
McM - J 1506/384	40.0	10.5	0.26	1.64	23.0	0.69

Aspidoceras cf. *A. andinum* Steuer, 1897

Pl. 36, fig. 1

?1825. *Ammonites longispinus* J. de C. Sowerby, Mineral Conch. Great Britain, vol. 5 (1825), p. 164, pl. 501, fig. 2.

?1897. *Aspidoceras andinum* Steuer, Paläont. Abhandl., N.F., Band 3, Heft 3, pl. 5, figs. 5-7 (Transl.: 1921, Actas Acad. Nac. Cienc. Córdoba, vol. VIII, p. 99, pl. 5, figs. 5-7).

?1897. *Aspidoceras cieneguitense* Steuer, *ibid.*, pl. 5, figs. 8-11. (Transl.: 1921, *ibid.*, p. 101, pl. 5, figs. 8-11).

- ?1906. *Aspidoceras quemadense* Burckhardt, Inst. Geol. México, Bol. 23, p. 154, pl. VI, figs. 1-4.
?1912. *Aspidoceras* aff. *longispinum* J. de C. Sowerby, *ibid.*, Bol. 29, p. 73, pl. XVI, fig. 7.
1961. *Spiticeras* (*Kilianiceras*?) cf. *euomphalum* Steuer, Sato, Japan. Jour. Geol. Geogr., vol. 32, p. 550, pl. XIII, fig. 2.

Material. — One distorted medium-sized probably adult phragmacone with well-preserved inner and outer whorls exposed on one side, from loc. 25 (McM - J 1517/86).

Description. — The shell is only moderately inflated and relatively evolute, with rounded probably somewhat subrectangular whorl section. There are two almost identical rows of prominent lateral spines. The inner row, on the umbilical shoulder, consists of long spines with about 45° inclination toward the umbilicus. The height of the nine spines present on the last preserved whorl ranges from about 10 mm to 25 mm. The outer row of about 12 spines per whorl is near mid-flank but is represented only by thick bases of the floored hollow spines. The rest of the shell is smooth except for some dense faint growth striations.

Remarks. — In spite of the distortion, the inner row of spines is remarkably well preserved although fractured. Our specimen resembles *A. andinum* Steuer (1897) in shell shape and ribbing. *A. cieneguitense* Steuer (1897), also from Argentina, appears to be closely similar. Another seemingly identical form from Argentina is "*A. aff. longispinum* Sowerby" of Burckhardt, 1912. Several species of Burckhardt from Mexico (see synonymy) clearly show great similarity with the European *A. longispinus* J. de C. Sowerby (1825), including the two rows of tubercles which were the bases, of floored hollow spines, the evolute rounded whorls, and the fine striations in absence of ribs. *A. haupti* Krantz (1928, p. 12, pl. IV, figs. 2a, b) from Argentina, has much smaller and more densely placed inner tubercles. *A. euomphalum* Steuer (1897) is much more inflated and involute. A specimen described by Sato (1961) as "*Spiticeras* (*Kilianiceras* ?) *euomphalum* Steuer" is almost certainly conspecific with *A. andinum* Steuer. Sato's misidentification most probably arose from an error in the Treatise figure of *Aspidoceras euomphalum* (see under remarks for *A. haupti* below).

Occurrence. — El Verde Member, La Caja Formation, Sierra Catorce.

Age. — Upper Tithonian.

Aspidoceras haupti Krantz, 1928

Pl. 36, fig. 2; Pl. 37, fig. 1

1928. *Aspidoceras haupti* Krantz, Acad. Nac. Cienc. Rep. Argentina, vol. 10, p. 12, pl. IV, figs. 2a, b.

Material. — One large nearly complete, somewhat distorted phragmocone, from loc. 23B (McM - J 1506/385).

Description. — The shell is large (the phragmocone measuring approximately 215 mm in diameter) and moderately evolute. The whorl section is depressed ovate and somewhat rectangular, with about 20% whorl overlap. The umbilical wall is steep, slightly rounded, and the venter weakly convex. There are two rows of lateral tubercles or spines of conical, somewhat elongate shape. The inner row is placed on the umbilical shoulder and consists of small rather densely and unevenly spaced tubercles. The outer tubercles, placed somewhat above mid-flank, are much more prominent, more distantly spaced and, therefore fewer in number. Some irregular ribs or plications appear to be present between the rows of tubercles. The venter has blunt ribs or undulations. The septal suture has a deep and wide E and a L of the same width and depth.

Remarks. — Our specimen is nearly identical with the holotype of *A. haupti* Krantz (1928) except for its greater diameter. The holotype of *A. euomphalum* Steuer (1897, pl. V, fig. 1) [erroneously figured in the Treatise, p. L346, fig. 454, 3a, b, as "*Spiticeras* (*Kilianiceras*) *damesi* (Steuer, 1897)"], also from Argentina, differs in the more prominent and widely spaced inner row of tubercles. *A. casitense* Imlay (1939, p. 32, pl. 5, fig. 7, pl. 6, fig. 11) from northern Mexico has also weak inner tubercles; however, these are equal in number to those of the outer row. *A. haupti* differs from *A. alamtocense* Aguilera (1895, p. 43, pl. XXII, fig. 6, pl. XXIII) by the greater evolution of the whorls, the much thinner tubercles, particularly of the inner row, and by the nearly smooth venter. The inner row of tubercles of *A. quemadense* Burckhardt (1906, p. 154, pl. VI, figs. 1-4) is as densely spaced as in *A. haupti*, but this is a much more compressed form.

Occurrence. — Virgatosphinctinae beds, upper part of El Pastor Member, La Caja Formation, Sierra Catorce.

Age. — Upper part of Lower Tithonian.

Measurements. —

	D	U	U/D	H	W	H/W
McM - J 1506/385	c.215.0	58.0	0.27	c.100.0	c.85.0	1.17

Aspidoceras cf. *A. haupti* Krantz, 1928 [? ♂] Pl. 35, fig. 3

?1928. *Aspidoceras haupti* Krantz, Acad. Nac. Cienc. Rep. Argentina, vol. 10, p. 12, pl. IV, figs. 2a, b.

Material. — Two small to medium size, moderately preserved phragmocones, probably incomplete, from loc. 23B (McM - J 1506/44, 332).

Description. — The whorls of the phragmocone are evolute and inflated with depressed subovate section. The wide umbilicus is moderately deep, the flanks are narrowly rounded and the venter broadly rounded. Of the two rows of lateral tubercles, the outer one is more prominent. Many tubercles in both rows are damaged. The venter is smooth.

Remarks. — The specimens differ markedly from *A. cf. A. alamitocense* by the absence of ventral undulations. Both phragmocones show indications of adulthood. They resemble the inner whorls, as far as known, of *A. haupti* and are, therefore, tentatively considered to be either juvenile or nuclei of macroconchs or microconchs. The smaller specimen, on account of better preservation, is figured here (Pl. 35, fig. 3).

Occurrence. — Virgatosphinctinae beds, upper part of El Pastor Member, La Caja Formation, Sierra Catorce.

Age. — Upper part of Lower Tithonian.

Measurements. —

	D	U	U/D	H	W	H/W
McM - J 1506/44	78.0	25.0	0.32	33.0	39.0	0.84
- J 1506/332	41.0	14.0	0.34	16.0	26.0	0.61

Genus *PHYSODOCERAS* Hyatt, 1900

Type species: *Ammonites circumspinosus* Quenstedt, 1858.

Although tubercles appear to be entirely missing in the species group of *Ammonites cyclotus* Oppel, except perhaps for the nucleus, these smooth involute forms described under several species particularly from Mexico and Argentina (see below) seem to be more closely affiliated with *Physodoceras* than with *Aspidoceras*. The

distinction of a new genus or subgenus may later become necessary.

Physodoceras (subgen. nov. ?) **burkarti** (Aguilera), 1895 Pl. 29, fig. 3

1895. *Nautilus burkarti* Aguilera in Castillo and Aguilera, Com. Geol. México, Bol. 1, p. 12, pl. XXI, fig. 3.

?1897. *Aspidoceras cyclotum* Oppel, Steuer, Paleont. Abhandl. Jena, N. F., Band 3, Heft 3, pl. VI, figs. 5, 6. (Transl.: 1921, Act. Acad. Cienc. Cordoba, vol. VII, p. 98, pl. VI, figs. 5, 6).

1906. *Aspidoceras cajense* Burckhardt, Inst. Geol. México, Bol. 23, p. 123, pl. XXXIII, figs. 5-8.

1906. *Aspidoceras phosphoriticum* Burckhardt, *ibid.*, p. 122, pl. XXXIII, figs. 1-4.

?1906. *Aspidoceras zacatecanum* Burckhardt, *ibid.*, p. 124, pl. XXXIII, figs. 9-12.

1906. *Aspidoceras cyclotum* Steuer (? Oppel), Burckhardt, *ibid.*, p. 119, pl. XXXII, figs. 3-6.

Material. — The holotype, a small somewhat deformed, probably complete phragmocone (UNAM 32), from "Rancho Alamitos, Sierra de Catorce, San Luis Potosí, México."

Description. — The small ($D = 47$ mm) phragmocone of the holotype is involute and highly inflated, with depressed subovate whorl section. The umbilicus is narrow and deep. The umbilical wall is steeply inclined and the shoulder is sharply rounded. The flanks are gently convex and the venter evenly rounded. The entire shell surface is smooth except for some obscure fine radial striations which appear to originate below the umbilical shoulder and cover the flanks in a sigmoidal curve. These striations probably continue on the venter. Etching has provided parts of an "ammonitic" septal suture.

Remarks. — Burckhardt (1906) described several similar "species" of highly involute nontuberculate "*Aspidoceras*" from his "Lower Portlandian" beds of Vereda del Quemado in the Mazapil area, e.g. "*A.* *cajense*", "*A.* *phosphoriticum*", and "*A.* *cyclotum* Steuer (? Oppel)". Burckhardt's moderately preserved material hardly permitted the distinction of new species; all of them appear to be nearly identical and closely resemble *P. burkarti*. They are, therefore, synonymised. "*A.* *zacatecanum* Burckhardt (1906), also from Mazapil, has a slightly wider umbilicus. "*A.* *fallax* (Burckhardt, 1906, p. 121, pl. XXXII, figs. 7-11) is also similar in whorl shape and dimensions but has pronounced striations. The well-known *Ammonites cyclotum* Oppel (1865, *fide* Zittel, 1870, p. 83, pl. 6, figs. 2-5) from southern Europe is similar to our species but has a narrower umbilicus and a more depressed whorl section. The "*A.*

cyclotum Oppel" described by Steuer (1897) from the Tithonian of Argentina appears to be nearly identical with *P. burkarti* in shell shape and ornamentation.

Occurrence.—"*Nautilus burkarti*" was reported by Aguilera (1895) from his "Los Alamos Beds". The nature of the matrix is identical to the Virgatosphinctinae beds of Los Alamos (Loc. 23 of this work).

Age.—Upper part of Lower Tithonian.

Measurements.—

	D	U	U/D	H	W	H/W
Holotype	47.0	6.0	0.12	26.0	32.5	0.80

Subfamily SIMOCERATINAE Spath, 1924

Genus SIMOCERAS Zittel, 1870

Type species: *Ammonites biruncinatus* Quenstedt, 1847 (SD Fischer, 1882).

Simoceras cf. *S. volanense* (Oppel), 1863

Pl. 37, fig. 2

1863. *Ammonites volanensis* Oppel, Palaeont. Mitt. Mus. k. bayer. Staates, Band 3, p. 231, pl. 58, fig. 2.
 1870. *Simoceras volanense* Oppel, Zittel, Palaeontographica, Suppl. Band 1, p. 95, pl. 8 (32), figs. 7-9.
 1929. *Simoceras* aff. *volanense* Oppel in Zittel, 1870, Krantz, Act. Acad. Nac. Cienc. Rep. Argentina, vol. 10, p. 13, pl. III, fig. 7.

Material.—One moderately preserved somewhat distorted specimen, from loc. 40C (McM - J 1528/10).

Description.—The shell is serpenticone with subquadrate to depressed subrectangular whorl section and an almost flat venter. The flanks have prominent blunt ribs between two rows of tubercles or spines, respectively on the umbilical and ventro-lateral shoulders. The venter is almost smooth, except for several blunt somewhat convex undulations and, possibly, constrictions. A constriction near the aperture may indicate that the shell is complete at 72 mm diameter.

Remarks.—The specimen closely resembles the Argentinian "*Simoceras* aff. *S. volanense* Oppel" described by Krantz (1928). The Mexican "*Nebroditites*" *aguilerae*, "*N.*" *quenstedti* and "*N.*" *nodocostatus*, Burckhardt spp. (1906, 1912), and "*Simoceras* sp." of Imlay (1939) are all more densely ribbed than our specimen.

Occurrence. — Virgatosphinctinae beds, Upper part of El Pastor Member, La Caja Formation, Sierra Catorce.

Age. — Upper part of Lower Tithonian.

Measurements. —

	D	U	U/D	H	W	H/W
McM - J 1528/10	72.0	39.0	0.54	17.0	19.0	0.89

Family **BERRIASSELLIDAE** Spath, 1922

Subfamily **BERRIASSELLINAE** Spath, 1922

Genus **BERRIASSELLA** Uhlig, 1905

Type species: *Ammonites privasensis* Pictet, 1867 (SD Roman, 1938).

Berriasella cf. **B. picteti** (Kilian), 1910

Pl. 37, figs. 3-4

?1867. *Ammonites privasensis* Pictet, *Melanges paléontologiques*, t. 1, 2 livraison, Geneve, p. 84, pl. XVIII, figs. 2a, b, c; *non* figs. 1a, b [= *B. privasensis*].

?1910. *Hoplites (Berriasella) picteti* Kilian, *Lethaea Geognostica*, 11, Mesozoicum, 3. Band: Kreide, Palaeocretacicum, pp. 181, 183, 184 [see Remarks below].

?1939. *Berriasella picteti* (Jacob *in* Kilian), *Mazenot*, Soc. Géol. France, Mém. 41, p. 42, pl. LL, figs. 1a, b; 2a, b.

(For more complete synonymy see Mazenot, 1939, pp. 42, 45, 46).

Material. — Ten specimens: five from loc. 1A (McM - J 1494/4, 64, 73, 109, 131); one from loc. 2 (McM - J 1495/71); one from loc. 18 (McM - J 1503/8); two from loc. 22 (McM - J 1508/27, 38); and one from loc. 24 (McM - J 1509/329). All specimens are whorl fragments, except for J 1494/4, a nearly complete slightly damaged phragmocone.

Description. — The shell is compressed, planulate, and rather evolute with subrectangular whorl section which is about one and a half times higher than wide. The narrow umbilical wall is fairly steep. The flanks are flat, subparallel. The venter is tabulate. The inner whorls have sharp, moderately spaced ribs, which originate at the umbilical seam somewhat rursiradiate but curve gently to cross the flanks rectiradiate with slight flexure. Bifurcation takes place between mid-flank and two-thirds whorl height. The secondaries pass straight over the venter with slight mid-ventral indentation. There are 35 primaries on the outermost whorl of the largest specimen.

Remarks. — Some confusion existed with regard to the designation of type specimens of *B. privasensis* and *B. picteti*, which Mazenot (1939, pp. 45, 46) tried to clarify. According to him, the two syntypes figured by Pictet (1867, pl. XVIII, figs. 1a, b and figs. 2a-c) under *A. privasensis* were originally regarded as specifically distinct by Jacob in an unpublished manuscript of 1904 in which he renamed Pictet's figures 2a-c as *Hoplites picteti*, implicitly designating figures 1a, b as the lectotype of *A. privasensis*. Kilian (1910) published Jacob's proposal, but apparently erroneously reversed the numbers of Pictet's figures (besides citing the wrong plate number, *i.e.* XVII instead of XVIII). Subsequent authors either used the two names interchangeably or created new species on essentially similar material. Mazenot (1939) finally stated clearly that the first specimen figured by Pictet (*op. cit.*, pl. XVIII, figs. 1a, b; refigured by Mazenot, 1939, pl. II, figs. 3a, b) is the lectotype of *Berriasella privasensis* while the second (*op. cit.*, pl. XVIII, figs. 2a, b; refigured by Mazenot, 1939, pl. II, figs. 1a, b) is the holotype of *B. picteti*. Although Jacob was the first to name *B. picteti*, technically the only authorship goes to Kilian (1910) as the first author in a published work.

Our specimens closely resemble *B. picteti* in coiling and ribbing but differ by the flatter flanks and the tabulate venter, while the smooth mid-ventral band is less distinct in our specimens. *B. picteti* is more inflated and more prominently ribbed than *B. privasensis*. Several Argentinian *Berriasella* species described by Steuer (1921), Krantz (1928), and Leanza (1945) appear to be smaller and more inflated than the forms from southeastern France; some also have a prominent mid-ventral furrow, *e.g.* *B. australis* Leanza, *B. argentina* Krantz, and *B. krantzi* Leanza.

Occurrence. — El Verde Member, La Caja Formation, Sierra Catorce.

Age. — Upper Tithonian.

Measurements (figured specimens only). —

	D	U	U/D	H	W	H/W	P
McM - J 1494/4	c.58.0	c.28.0	0.48	c.18.5	c.13.0	1.42	35/outer wh.
- J 1503/8	—	—	—	c.25.0	c.11.5	2.17	14/1/4 wh.

Berriasella lorioli (Zittel)?, 1868

Pl. 37, fig. 5; Pl. 38, figs. 1-2

Material. — Five whorl fragments: one from loc. 1 (McM - J 1494/38); one from loc. 2 (McM - J 1495/49); two from loc. 25 (McM - J 1517/72, 79); and one from loc. 15 (McM - J 1535/13).

Description. — It appears that the shell is planulate. The whorl section is subrectangular, about one and a half times higher than wide. The umbilical wall is steep. The flanks are almost flat and separated from the venter by marked shoulders. There are coarse equally spaced prorsiradiate ribs, with interspaces almost twice as wide as the ribs, bifurcating at about mid-flank while simple ribs are rare. Occasionally, virgatotome ribs are present. The secondaries cross the venter with slight mid-ventral indentations.

Remarks. — Our specimens are too fragmentary for a precise specific determination. However, they resemble *B. lorioli* (Zittel, 1868, p. 103, pl. 20, figs. 6-8) from the Upper Tithonian of south-eastern France (see Mazenot, 1939, p. 125, pl. 19, figs. 3-7). In coarseness of ribs our specimens are similar to *B. grandis* Mazenot (1939, p. 133, pl. XXII, figs. 3a, b; 6a, b), but they differ by the occasional occurrence of simple and virgatotome ribbing. Moreover, according to Hegarat and Remane (1968), *B. grandis* is a typically Berriasian species. The Argentine *B. krantzi* Leanza (1945, p. 32, pl. VI, figs. 7, 8) has a somewhat similar rib pattern but is much thicker. In the absence of complete specimens, the assignment of our material to *B. lorioli* is only tentative.

Occurrence. — El Verde Member, La Caja Formation, Sierra Catorce, Mexico.

Age. — Upper Tithonian.

Measurements (figured specimens only). —

	H	W	H/W
McM - J 1494/38	32.0	20.0	1.60
- J 1517/72	25.0	13.5	1.65
- J 1535/13	24.0	13.5	1.77

Berriasella subprivasensis Krantz, 1928

Pl. 38, figs. 3-5

?1895. *Perisphinctes* sp. Aguilera in Castillo and Aguilera, Com. Geol. México, No. 1, p. 25, pl. 19.

1928. *Berriasella subprivasensis* Krantz, Act. Acad. Nac. Cienc. Rep. Argentina, vol. X, p. 20, pl. III, figs. 4a, b.

Material. — Nineteen specimens, mostly fragments of phragmocone and/or body chamber, somewhat distorted: seven from loc.

22 (McM - J 1508/104, 105, 107-111); one from loc. 24 (McM - J 1509/330); two loc. 32 (McM - J 1511/49, 341); one from loc. 34 (McM - J 1513/118); four from loc. 19A (McM - J 1515/10, 17, 22, 25); three from loc. 25 (McM - J 1517/23, 33, 37); one from loc. 15 (McM - J 1535/25); and one from loc. 16 (McM - J 1536/12).

Description. — The relatively large shell is planulate, somewhat evolute. The whorl section is subrectangular with weakly convex flanks which curve into the convex venter. The umbilicus appears to be fairly wide. The ornament consists of prominent thick ribs which arise at the umbilical seam, are rursiradiate on the umbilical slope and sinuously prorsiradiate on the flanks. Some ribs remain simple, others bifurcate at or just above mid-flank. In general, the number of biplicate ribs predominates over simple ribs; intercalatories are absent. The septal suture (Pl. 38, fig. 5) is moderately complicated. It has a broad E, a somewhat deeper and broad L, and two, possibly three suspensive U's of diminishing depth. The E/L saddle is narrow with deep incisions.

Remarks. — Our fragments closely resemble the outer whorls of *B. subprivasensis* Krantz (1928) in ribbing and whorl section. All other South American and Mexican species differ in cross section and denser ribbing. Among the European species, *B. douvillei* (Matheron, 1880, pl. B-2, fig. 2; *fide* Mazenot, 1939, p. 100, pl. XIV, figs. 4a, b) is somewhat similar. *B. latecostata* (Kilian, 1910; *fide* Mazenot, 1939, p. 109, pl. XVI, figs. 1a, b, 5a, b) is another large species of *Berriasella*, which resembles *B. subprivasensis* in dimensions but does not appear to have biplicate ribs; most ribs are simple or intercalatories. The specimen described under "*Perisphinctes* sp." by Aguilera (*in* Castillo and Aguilera, 1895), although badly covered with matrix, has coarse ribs on flanks and venter, resembling those of *B. subprivasensis*.

Occurrence. — El Verde Member, La Caja Formation, Sierra Catorce.

Age. — Upper Tithonian.

Measurements (figured specimens only). —

	H	W	H/W
McM - J 1508/110	c.35.0	c.21.0	1.66
- J 1511/341	39.0	26.0	1.50
- J 1517/33	70.0	c.45.0	1.55

Berriasella aff. **B. zacatecana** Imlay, 1939

Pl. 39, figs. 1-3

Material. — Thirty-three specimens: twenty-four from loc. 1A (McM - J 1494/40, 42, 43, 48, 55, 56, 57, 63, 66, 74, 85, 98, 105, 114, 119, 124, 150, 156, 188 to 193); seven from loc. 2 (McM - J 1495/13, 23, 63, 73 to 76); one from loc. 10 (McM - J 1501/39); and one from loc. 32 (McM - J 1511/79). Most specimens are whorl fragments stained with various shades of yellow or pink, preserved as light grey internal molds. This preservation differs from that of the associated fauna, e.g. *Kossmatia* and *Substeuerceras*, which occurs as dark grey internal molds. Many specimens were found scattered over the upper part of the San Andres outcrop (loc. 1A); however, their colored pinkish grey source bed was located near the top of the section.

Description. — The shell is planulate and moderately involute with compressed subrectangular whorl section. The umbilicus is wide and shallow with steep umbilical slope. The inner whorls have regular weak ribs which arise at the umbilical seam, are rursiradiate on the umbilical shoulder, and become prorsiradiate at mid-flank. The ribs on the outer whorls are similar and somewhat flexed. The secondaries are weakly projected and terminate at the mid-ventral region with a faint swelling, leaving a smooth central band.

Remarks. — A comparison of our specimens with the Mexican *B. zacatecana* Imlay (1939, p. 52, pl. 18, figs. 4, 7-10) indicates that *B. zacatecana* has laterally more strongly flexed ribbing. Our specimens probably represent a closely related species; but in the absence of better preserved and more complete material, this judgement is only tentative.

Occurrence. — El Verde Member, La Caja Formation, Sierra Catorce.

Age. — Upper Tithonian.

Measurements. —

	D	U	U/D	H	W	H/W	P/¼ wh.
<i>B. zacatecana</i>	c.58.0	20.0	0.34	23.0	17.5	1.31	12
Holotype (UM 19295)	—	—	—	20.0	13.0	1.53	—
Paratype (UM 19293)	—	—	—	12.3	11.3	1.08	c.12
McM - J 1494/191	—	—	—	12.5	12.0	1.04	—
- J 1494/42	38.5	16.0	0.41	12.5	12.0	1.04	—
- J 1494/66	—	—	—	19.0	15.0	1.26	—

Genus **KOSSMATIA** Uhlig, 1907

Type species: *Ammonites tenuistriatus* Gray 1830-1832 (SD Roman, 1938).

In the Sierra Catorce, *Kossmatia* occurs abundantly, stratigraphically below *Substeuerocheras*, in the El Verde Member of the La Caja Formation. Of the more than 200 specimens collected from these beds, more than half were in a fairly good state of preservation. This sample permits a rather detailed study of inter- and intraspecific variation and the taxonomic revision of the previously described "species".

Discussion.—The genus *Kossmatia* was proposed by Uhlig (1907, p. 267) for

very flat, disc-shaped, rather narrowly umbilicated ammonites with narrow rounded, more rarely slightly flattened external margin [tabulate venter] and a rounded umbilical wall. On the upper part of the whorl, the ribs may break into two or three or even four subsidiary branches which may become associated with intercalatory ribs. If more than two subsidiary ribs are present, they originate at different heights in the same manner as in *Sibirskites*. All the ribs assume a decided anterior inclination on the upper part of the whorls and constitute an anterior convex arch on traversing the external margin. In many forms, the ribs along the entire length of the flanks form posteriorly convex arches; in others, they exhibit a shallow anteriorly convex curvature in the middle region of the flanks.

An important attribute which distinguishes *Kossmatia* from the morphologically similar and stratigraphically associated genera "*Paradontocheras*" and *Substeuerocheras* is the orad convex arching of the ribs as they traverse the venter. This character was stressed in Uhlig's original discussion but has not received due consideration in the Treatise (Arkell, *et al.*, 1957, p. L323). Uhlig considered this character so important that he illustrated the holotype of *K. tenuistriata* for the fourth time giving the ventral view which was missing in the earlier figures of Gray (*in* Hardwicke, 1830-32), Blanford (*in* Salter and Blanford, 1865), and Siemiradzki (1898-99). Uhlig listed the following four species under *Kossmatia*, without designation of the type species:

Stephanocheras eucyclum Waagen

Ammonites tenuistriatus Gray

Kossmatia desmidoptycha Uhlig

Ammonites richteri Oppel

Of these, the Callovian "*Stephanocheras*" *eucyclum* was trans-

ferred by Spath (1925, Blake Coll. p. 8) to his genus *Eucycloceras*. Of the remaining three, Roman (1938) designated *A. tenuistriatus* Gray from the Spiti Shales, Himalayas, as the type species. Unfortunately, the stratigraphic position of this species at the type locality is not known. According to Mousterde, *et al.* (1971), in the Spiti Shales of Nepal Himalayas, both *K. tenuistriata* and *K. desmidoptycha* occur in the basal part of the Upper Tithonian.

A. richteri from the Tithonian of the Alps appears to be well established because it was based on a sample of over 50 specimens. The description of *K. desmidoptycha* from the Spiti Shales rests on a sample of four specimens only. The type species *K. tenuistriata*, as described and figured by Gray (*in* Hardwicke, 1830-32), Blanford (*in* Salter and Blanford, 1865), Siemiradzki (1898-99), and Uhlig (1907), appears to have been established on two specimens only, the larger one being Gray's original type specimen and, therefore, the holotype. The essential difference between *K. desmidoptycha* and *K. tenuistriata* is the presence of much stronger primaries breaking up into several branches in the former and only biplicate ribs in the latter.

Burckhardt (1912) dealt with *Kossmatia* from the Americas in detail and included several of his "*Perisphinctes*" species described earlier from Mazapil (1906):

K. victoris (Burckhardt)

[*K. aff. victoris*]

K. burkarti (Burckhardt)

K. santarosana (Burckhardt)

to which he added

K. zacatecana Burckhardt

also from Mazapil. In addition, he described two more species from San Pedro del Gallo:

K. interrupta Burckhardt

K. pectinata Burckhardt

Thus Burckhardt named six *Kossmatia* species from the Jurassic of Mazapil and San Pedro del Gallo in northern Mexico. He (1912, p. 131) also discussed the genus in some detail including the septal suture, and for the first time, pointed to the importance of *Kossmatia* in the Americas.

Burckhardt's Mexican material was, however, small in number

and fragmentary. Most of his "species" were based on one or two internal molds which were described in great detail, but their differences appear to be subtle. In fact, these "species" seem to intergrade into each other, especially in whorl shape and coiling. If Burckhardt had had more material at his disposal, he probably would have observed enough variation and erected fewer "species". His comparisons between any two "species" are characterized by such phrases as "broader whorls", "narrower umbilicus", "higher umbilical wall", so that the "species" can be identified only after a detailed consideration of the shell dimensions in conjunction with ornament (*i.e.* mainly biplicate, triplicate or virgatotome ribs, ventral interruption *vs.* continuity, height of division, projection, presence *vs.* absence of constrictions). Even then, several groups of two or more species appear to be so closely similar, that they can only be regarded as conspecific.

An example is the pair *Kossmatia pectinata* — *K. zacatecana*; both are small, somewhat evolute shells with moderately depressed whorl section and small growth rate, fairly prominent widely spaced biplicate ribbing, weak constrictions, and similar ventral arching of the ribs with mid-ventral depression. Of the two, *K. zacatecana* is represented by smaller but more completely preserved specimens. Similarly, *K. victoris* (with "*K. aff. victoris*" and "*K. cfr. victoris*") and *K. burkarti* appear to be synonymous. Both have rectangular cross section, a wide umbilicus, primaries which branch out with bifurcating, trifurcating or virgatotome branching, and in addition, intercalatory ribs. The secondaries are similar in projection and mid-ventral depression. According to Burckhardt (1906, p. 134), *K. victoris*, although closely related to *K. burkarti*, is distinguished by "the whorls being a little thicker, a higher umbilical wall, and consequently a deeper umbilicus. The ribs are more widely spaced and more projecting. The suture is distinguished notably by the structure of the first lateral lobe which is longer and broader than in *K. victoris*" [our translation]. In our opinion, these differences fall within the limits of infraspecific variation. Since *K. victoris* is based on two moderately good specimens, whereas *K. burkarti* is known only in four incomplete fragments, it is proposed to retain the former name. *K. aff. victoris* of Burckhardt (1906, pl. XXXVII, figs. 7-9, 10-12, 15) and *K. cfr. victoris* of Burckhardt (1906, pl. XXXVI,

figs. 13-14) do not appear to differ significantly from *K. victoris* (Burckhardt 1906, pl. XXXVI, figs. 1-6).

K. interrupta Burckhardt (1912, pl. XXXIV, figs. 2, 3, 15) is based on a single distorted and incomplete small specimen, probably a microconch. Burckhardt considered this "species" as closely affiliated to *K. richteri* Oppel (cf. Zittel, 1868, pl. 20, figs. 9a-d) from the Alps and, particularly, to "*Perisphinctes* cfr. *richteri*" described by Behrendsen (1891-92) from Argentina. Our collection includes one specimen identical with "*K. interrupta*", a microconch which is here regarded as conspecific with *K. flexicostata* (Aguilera).

K. santarosana (Burckhardt, 1906) from Mazapil was based on a large single specimen with crushed ultimate quarter whorl. It, too, appears to closely match *K. flexicostata* (see below) in whorl shape, coiling, style of ribbing, and the ventral chevrons. "*Kossmatia* sp. indet." of Burckhardt (1906, pl. XXXVIII, figs. 9, 11, 12), although weathered, closely resembles "*K. santarosana*".

Burckhardt's six "new species" of *Kossmatia* from San Pedro del Gallo and Mazapil are thus reduced to three as follows:

K. victoris Burck. [Syn.: *K. burkarti* Burck.]

K. zacatecana Burck. [Syn.: *K. pectinata* Burck.]

K. flexicostata (Aguil.) [Syns.: *K. interrupta*, *K. santarosana* Burck.]

Burckhardt (1912) assigned the following species of Aguilera (in Castillo and Aguilera, 1895) from the Sierra Catorce to *Kossmatia*:

Perisphinctes flexicostatus Aguil.

P. alamosensis Aguil.

Hoplites calisto var. Aguil. (pl. XXII, fig. 2)

Hoplites exceptionalis Aguil.

Rhacophyllites disputabilis Aguil.

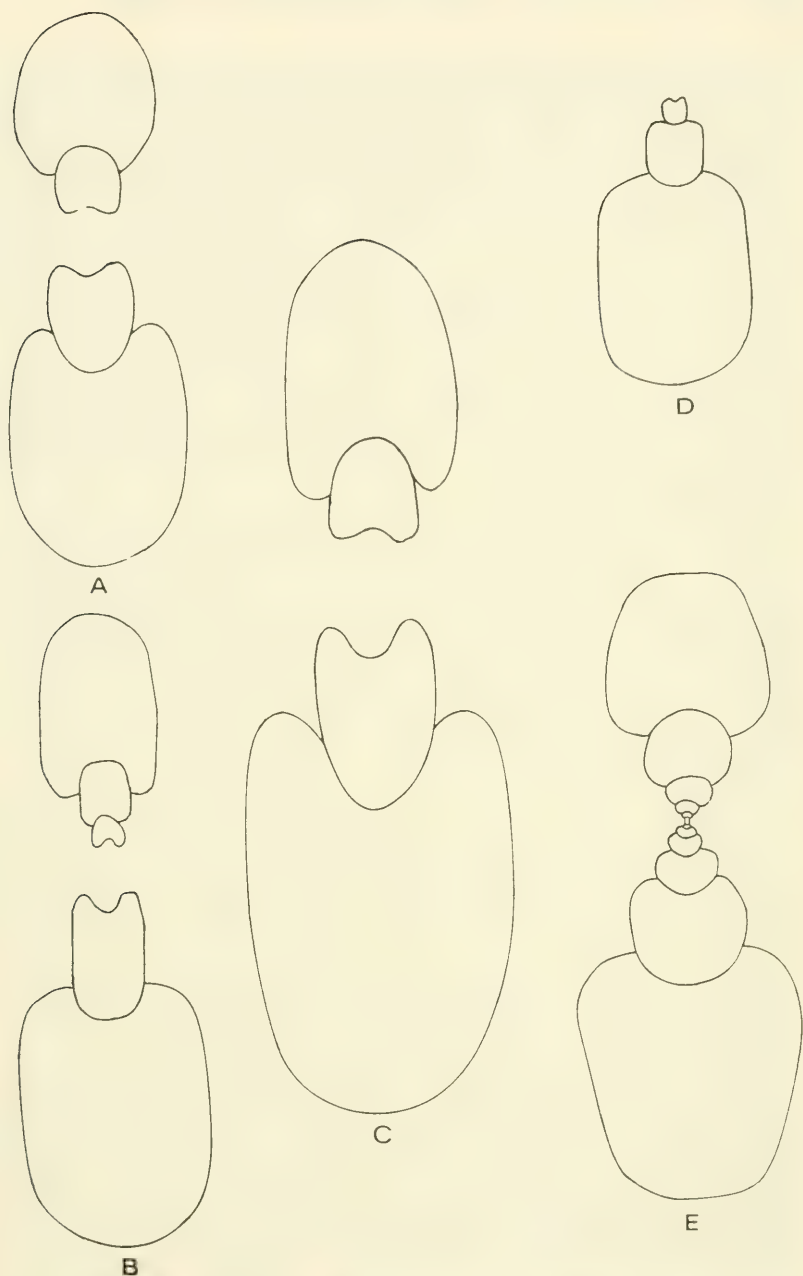
Through the courtesy of the Instituto de Geología, Universidad Nacional Autónoma de México, we were able to study the available type material of Aguilera. Supplementing this with our own collection, we have concluded that the *Kossmatia* material of Sierra Catorce comprises five distinct species one of which is new. They are:

Kossmatia alamosensis (Aguil.) [= *Perisphinctes alamosensis* Aguil.]

- Kossmatia bifurcata* (Aguil.) [Syn.: *Hoplites mexicanus* Aguil.]
Kossmatia exceptionalis (Aguil.) [Syns. *Rhacophyllites* ?
alamitosensis Aguil.; *R.* ? *disputabile* Aguil.]
Kossmatia flexicostata (Aguil.) [Syns.: *K. santarosana*
(Burck.); *K. interrupta* (Burck.)]
Kossmatia purissima n. sp. [? Syns.: *Hoplites calisto* (d'Orb.)
var. Aguil. (pl. XXII, fig. 2, non pl. XI, fig. 2); *K. kleinsor-*
gensis Anderson (nom. dub.); *K. potosina* Burck., 1930 (nom.
nud.)]

Imlay (1939) in his faunal list of Upper Jurassic ammonites from Mexico assigned "*Hoplites*" *mexicanus* and "*Hoplites*" *bifurcatus*, Aguilera spp., to *Paradontoceras* Spath, and "*Hoplites*" *exceptionalis* Aguilera to *Substeuerceras* Spath. No discussion was given. However, their attributes do not militate against the generic diagnosis of *Kossmatia* as originally proposed by Uhlig (1907). While the lateral style of ribbing may resemble that of "*Paradontoceras*" or *Substeuerceras*, all three species show ventral arching of ribs. Later, Imlay (1943, p. 537) stated that in *Kossmatia*, ventral arching is variable becoming more pronounced in the outer whorls. The type specimens of the species under discussion, however, appear to be adult phragmocones, so that there should be no objection to placing them in *Kossmatia*. We regard ventral arching as diagnostic of *Kossmatia*.

In 1943, Imlay described three new species of *Kossmatia* from the "Upper Portlandian" of the Placer de Guadalupe district in Chihuahua, Mexico, i.e., *K. varicostata*, *K. kingi*, and *K. rancheriasensis*. The material is well preserved and the specific differences from other *Kossmatia* species were clearly established; all are more inflated, larger in diameter and have different ornament (note that Imlay's pl. 92, figs. 3, 4 are approximately 3/4 natural size, and that pl. 94, fig. 4 was probably erroneously referred to *K. kingi* instead of *K. rancheriasensis*). Imlay (*op. cit.*) also extensively discussed *Kossmatia* from Mexico stressing its significance to the North American Jurassic. He noted the great diversity in form, size and sculpture, discounting claims of generic distinction from the Asian and European relatives.



Text-fig. 16. — Cross sections through the phragmocones of *Kossmatia* spp. A. *K. alamosensis* (Aguilera) [$? \delta$], McM - J 1527K/1, $\times 1.6$. B. *K. bifurcata* (Aguilera) φ , McM J 1517/67, $\times 0.55$. C. *K. exceptionalis* (Aguilera) φ , McM - J 1527A/3, $\times 0.8$. D. *K. flexicostata* (Aguilera) φ , McM - J 1535/4, $\times 0.8$. E. *K. purissima*, n. sp. McM - J 1501/2, $\times 1.5$.

Recently, Imlay and Jones (1970) reviewed and refigured from the Tithonian of northern California three earlier named *Kossmatia* species, each represented only by the fragmentary holotype: *K. dilleri* (Stanton, 1896), *K. tehamaensis* and *K. kleinsorgensis*, Anderson spp. (1945). Although comparison is obscured by the unsatisfactory material, Imlay and Jones supposed that *K. dilleri* resembles *K. victoris* and *K. aff. victoris* of Burckhardt; that *K. tehamaensis* is also similar to *K. aff. victoris*; and that *K. kleinsorgensis* resembles *K. pectinata* Burckhardt. *K. kleinsorgensis* is based on a whorl fragment only and, therefore, considered to be a *nomen dubium*. In view of the apparent close affinities to Mexican species, it is highly desirable that additional material be recovered from the California localities so that morphologic variation can be studied and affinities established.

Krantz (1928) described two specimens from the Tithonian of Mendoza, Argentina, under the new name *K. pseudodesmidoptycha* (pl. 1, figs. 4a, 5a, b, c). The smaller one (fig. 5) may be misplaced in *Kossmatia*, because of the much more widely spaced ribs, the apparent lateral tubercles, and the ventro-lateral tubercles bordering on a smooth mid-ventral area. He described a third, incomplete specimen from Mendoza (pl. 3, figs. 2a, b, c) under *K. sp. ind. aff. K. burkarti*.

Stratigraphic position and age.—Based on the better known occurrences in Spiti, southern Europe, Mexico, California, and the somewhat lesser known occurrences in Texas, South America, and New Guinea, the age of *Kossmatia* has generally been considered to be Upper Tithonian (= "Upper Portlandian" of some authors). The only exception to this appears to be the occurrence in the Kawhia Harbour sequence of New Zealand which Fleming and Kear (1960) placed in the Middle Kimmeridgian (see below).

The exact locality, stratigraphic position, and age of the type species *K. tenuistriata* in Spiti are unknown. *K. desmidoptycha* was reported from the Upper Spiti Shales of the Upper Tithonian (Uhlig 1907). Recent work by Mousterde, *et al.* (1971) on a sequence equivalent to the Spiti Shales in the region of Thakkola in the Nepal Himalayas has established the stratigraphic occurrence of several important Himalayan ammonite genera, including *Kossmatia*. Their preliminary stratigraphic account indicates that *K. tenuistriata* and

K. desmidioptycha occur in the basal part of the Upper Tithonian while other species occur in the middle part of the Upper Tithonian. *Kossmatia* is reported in association with *Blanfordiceras*, *Paraboli-ceras*, *Virgatosphinctes* and *Aulacosphinctoides*. Detailed paleontological descriptions of these and other important ammonites from Nepal will undoubtedly solve many of the old uncertainties concerning the Spiti Shales fauna.

K. richteri (Oppel) from Southern Europe has been reported to range from the Lower Tithonian to the Berriasian (Mazenot, 1939, p. 129; Zittel, 1868, pp. 108, 109). However, Enay (1973), maintains that *K. richteri*, the only Mediterranean species, occurs in the middle part of the Tithonian. All of Burckhardt's *Kossmatia* species from Mazapil and San Pedro del Gallo occur in association with *Durangites* in the middle part of his "Upper Portlandian"; stratigraphically above *Aulacosphinctoides*, *Subplantes*, and *Torquatisphinctes* of Upper Kimmeridgian and Lower Tithonian age, and below *Substeuroceras* of undisputed Upper Tithonian age (Burckhardt 1912, p. 221, 1930, tables 6, 11). Imlay (1939) corrected an error in Burckhardt's succession placing the beds with *Proniceras* below those with *Kossmatia*, and established the *Proniceras* occurrence to be above *Kossmatia* and *Durangites*. *K. kingi*, *K. varicostata* and *K. rancheriasensis*, Imlay spp., occur in Chihuahua at the same stratigraphic position as Burckhardt's *Kossmatia* species (Imlay, 1943, p. 531).

In Argentina, Krantz (1928, p. 49) placed his *Kossmatia pseudodesmidioptycha* in the uppermost Tithonian; above his Zone of *Necomites keyseri*, which overlies his Zone of *Parodontoceras calistoides* containing *Corongoceras*.

The exceptional, apparently Kimmeridgian occurrence of *Kossmatia* in New Zealand needs detailed discussion. Until 1956, students of New Zealand Jurassic ammonites considered the *Kossmatia* occurrence from the south shore of Kawhia Harbour as Upper Tithonian (Boehm, 1911, Spath, 1923, Marwick, 1953, and Arkell, 1956, p. 454). Preliminary identifications by the late W. J. Arkell of new collections and field work by Fleming, Kear, Waterhouse, and Stevens in 1954-56 (Fleming and Kear, 1960) indicated that *Kossmatia* occurred at several horizons in the Kawhia Harbour

sequence. Their sequence, with some simplification, is as follows:

Stage	Zone	<i>Kossmatia</i> species and important associated genera
Lower Tithonian	<i>Aulacosphinctoides brownei</i>	<i>Kossmatia</i> , n. sp. C, <i>Torquatisphinctes</i> (?), <i>Aulacosphinctoides</i> spp.
	<i>Paraboliceras</i> , n. sp. A.	<i>K.</i> cf. <i>desmidoptycha</i> , <i>K.</i> cf. <i>novoseelandica</i> , <i>K.</i> n. sp. B., <i>Paraboliceras</i> spp.
"Middle" to Lower Kimmeridgian	<i>Kossmatia</i> , n. sp. A.	<i>K. novoseelandica</i> (type specimens), <i>K.</i> aff. n. sp. A, <i>K.</i> ? n. sp. A, <i>Aspidoceras</i> , <i>Idoceras</i> , <i>Paraboliceras</i> ?, <i>K.</i> n. sp. A.
	<i>Idoceras</i> , n. sp. aff. <i>humboldti</i> and <i>Epicephalites</i> cf. <i>epigonous</i>	<i>Idoceras</i> spp. <i>Subneumayria</i> , <i>Epicephalites</i> .

Because of the occurrence mainly above as well as associated with the Kimmeridgian genera *Idoceras*, *Aspidoceras*, *Subneumayria*, and *Epicephalites*, and below *Aulacosphinctoides* of Upper Kimmeridgian to Lower Tithonian age, *Kossmatia* was dated as Lower "Middle" Kimmeridgian (Fleming and Kear, 1960, p. 44). On account of this early occurrence, Arkell (Treatise, p. L323, footnote 2) transferred *Kossmatia*, along with *Paraboliceras* and *Paraboliceratoides*, from the Tithonian family Berriasellidae to the Kimmeridgian family Ataxioceratidae (although retaining the illustrations of these genera together with other members of the family Berriasellidae).

However, before this transfer is accepted or confirmed, certain questions need to be answered. Firstly, while arguing for the transfer, Arkell emphasized the uncertainty associated with the Tithonian age of the different *Kossmatia* type species in Spiti (Treatise, p. L323, footnote 2; cf. quotations from Arkell's letters in Fleming and Kear, 1960, p. 33, 37). Yet neither Arkell nor Fleming and Kear made reference to southern Europe, Mexico, northern California, and South America, where *Kossmatia* is restricted to the well-established Tithonian. The Kimmeridgian age of the genus in New Zealand only would indeed be surprising, especially since faunal migrations at this time between New Zealand and Mexico

Measurements of type specimens of important *Kosareella* species other than those present in Sierra Catorce. —

	D	U	U/D	H	W	W/W	P/H _{wh.}	S/H _{wh.}	α
<i>K. Fichteri</i> (Oppel)	76.0	28.0	0.36	28.0	11.0	2.54	14	28	--
	63.0	19.0	0.30	23.0	9.0	2.55	13	25	60
	52.0	20.0	0.38	19.0	8.0	2.37	13	24	55
	44	17.0	0.38	16.0	6.0	2.66	12	--	--
<i>K. victoris</i> (Burek.)	60.00	26.00	0.43	22.00	16.00	1.37	12	c.27	--
	51.00	18.00	0.35	19.00	13.00	1.46	--	--	60
	--	--	--	--	--	--	11	c.27	61
<i>K. aff. victoris</i> (Burek.)	52.5	21.00	0.40	21.00	15.00	1.40	--	13	--
				12.0	12.0	1.00	9	13	60
<i>K. burkarti</i> (Burek.)	43.0	18.5	0.43	17.0	16.0	1.06	10	80	--
<i>K. zacataeana</i> (Burek.)	25.00	12.00	0.44	9.5	11.00	.86	8	--	--
	23.00	10.00	0.43	8.0	11.00	.72	--	--	72
<i>K. interrupta</i> (Burek.)	76.00	35	0.46	30.00	21.00	1.43	15	30	45
<i>K. pectinata</i> (Burek.)	30.5	15.0	0.49	10.0	12.0	0.83	--	--	65
<i>K. santarosana</i> (Burek.)	113.0	44.0	0.38	47.0	c.25	1.88	21	35	--
	103.0	34.0	0.33	42.0	--	--	17	32	--
	92.0	36.0	0.39	39.0	--	--	16	--	--
<i>K. varicostata</i> Imlay									
Holotype	149.00	66.5	0.44	50.0	40.0	1.25	c.26	60	45
	109.00	46.5	0.42	35.0	35.0	1.00	c.14	30	62
	101.00	45.0	0.44	31.0	25.0	1.24	14	28	60
Paratype (USNM 103366)	--	--	--	55.0	42.0	1.31	c.26	49	38
	--	--	--	42.0	37.5	1.12	--	--	37
Paratype (USNM 103365)	c.235	110.0	0.46	78.0	c.70.0	1.11	21	--	c.60
	c.175	75.0	0.42	73.0	c.40.0	1.32	--	--	c.44
	c.160	64.0	0.40	50.0	c.45.0	1.11	--	--	--
<i>K. kingi</i> Imlay									
Holotype	--	--	--	62	64	1.00	9	25	47
	--	--	--	61	49	1.24	--	--	48
Paratype (USNM 103368)	--	--	--	53.0	47	1.12	c.13	39	47
	--	--	--	46.0	44	1.04	--	--	52
Paratype (USNM 103369)	112	53.0	0.47	37.0	31.0	1.19	--	--	--
	c.87	43.0	0.49	c.27.0	c.26.0	1.03	--	--	--
	c.79.0	40.0	0.50	23.0	25.0	0.92	--	--	--
<i>K. zuncheriasensis</i> Imlay									
Holotype	--	--	--	73.0	70.0	1.04	c.4	--	--
	--	--	--	72.0	60.0	1.20	--	--	--
<i>K. tehaensis</i> Anderson	48.0	17.0	0.35	18.0	13	1.38	13	20	--
	41.0	14.0	0.34	16.0	13	1.23	--	--	57
	32.0	12.0	0.37	13.5	11	1.23	--	--	--
	31.0	11.0	0.35	12.0	11.0	1.09	11	20	50
<i>K. dilleri</i> Stanton	25.0	9.0	0.36	9.0	10.0	0.9	11	c.22	55
	20.0	8.0	0.40	7.0	10.0	0.7	--	--	57

are indicated by the common occurrence of *Idoceras*, *Epicephalites*, and *Subneumayria*.

Secondly, the only *Kossmatia* figured from New Zealand is *K. novoseelandica* (Hochstetter), although many specimens with affinities to *Kossmatia* have been described (Spath *in* Trechmann, 1923, pp. 302, 303; Marwick, 1953, pp. 121, 122). The alleged holotype of *A. novoseelandicus* Hochstetter (1863) was figured by Hochstetter (Eng. Trans. 1867) and by Hauer *in* Zittel (1864) as "*A. novo-zelandicus*". However, the specimen is reported to have been lost, and Arkell (*in litt.*) confirmed Fleming's suggestion that the figures were restorations of a crushed specimen of *Kossmatia* or *Paraboliceras* (Fleming and Kear, 1960, p. 32); we agree with Spath (1923) and Marwick (1953) that the whorl shape and venter as given in Hauer's illustration (copy: Marwick, 1953, pl. 16, figs. 1, 2) indicate that it is a *Berriasella*. To our knowledge, "*Kossmatia* spp. nov. A, B, C" of Fleming and Kear and the two unnamed species "*Kossmatia* n. spp. 1 and 2" of Spath referred to by Marwick (1953, p. 122) have not been described or figured. Consequently, it is to date not possible to comment on the affinities of these supposedly new *Kossmatia* species, and the transfer of the genus from the Berriasellidae to the Ataxioceratidae appears to be premature. *Kossmatia* is, therefore, retained in the Berriasellidae.

Enay (1973) has expressed similar doubts about the supposedly anomalous occurrence of *Kossmatia* in New Zealand. He believes that *Kossmatia* is restricted to the Upper Tithonian as again confirmed by the *in situ* occurrence in Nepal (Mouterde, *et al.*, 1971).

***Kossmatia alamitosensis* (Aguilera), 1895 [♀ + ?♂]**

Pl. 39, figs. 4-7; Pl. 40, fig. 1; Text-figs. 16A, 17A, 18

1895. *Perisphinctes alamitosensis* Aguilera *in* Castillo and Aguilera, Com. Geol. México, Bol. 1, p. 30, pl. XXI, figs. 4, 6, [fig. 6, lectotype, here designated].

Material.—Seventeen specimens, mostly complete or fragmental phragmocones: one from loc. 1 (McM - J 1494/160); one from loc. 18 (McM - J 1503/1); three from loc. 14K (McM - J 1515B/2, 3, 4); two from loc. 25 (McM - J 1517/5, 10); one from loc. 3 (McM - J 1522/6); seven from loc. 19D (McM - J 1526/9, 11, 14, 16, 18, 24, 26, 66); one from loc. 14G (McM - J

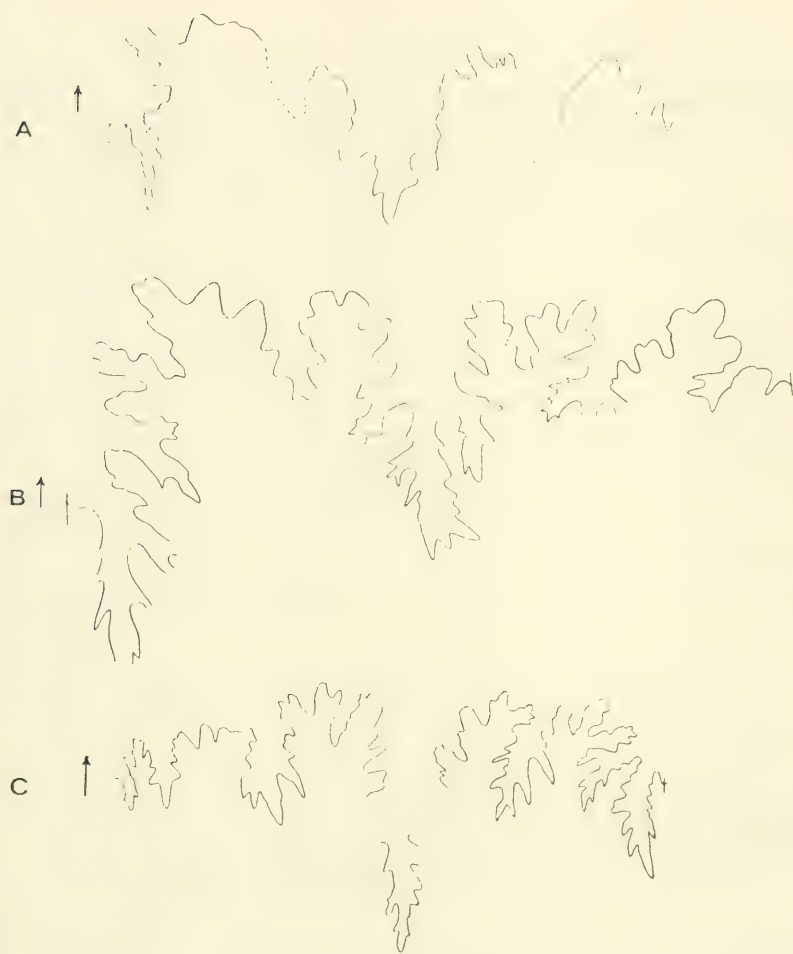
1527D/3); and one from loc. 14N (McM - J 1527K/1). The body chamber appears to have been destroyed by crushing and deformation. Many phragmocones are partly crushed or covered on one side with firmly cemented matrix. While the majority of specimens appears to be macroconchs, specimens J 1526/14, 16 and J 1527D/3 are probably microconchs.

Description. — The species is of moderate size, with the diameters of the phragmocones ranging from 50 mm to 110 mm. The phragmocone is planulate, with moderately wide umbilicus ($U/D = 0.3 - 0.4$). The whorl section is subcircular to compressed elliptical, the H/W ratio ranging from 1.00 to 1.65 (Text-fig. 16A). The inner whorls have irregular, widely spaced blunt ribs ($c.5\frac{1}{4}$ whorl). On the outer whorls of the phragmocone the ribs ($6-8\frac{1}{4}$ whorl) arise just below the umbilical shoulder and after a short rursiradial course become almost rectiradial. Adjacent ribs with low relief enclose gently curved interspaces. Irregularly, about every fourth rib bifurcates at two-third whorl height maintaining low relief, while others remain simple. Along the ventral margin, the ribs are strongly projected forming linguiform chevrons. The illustrated septal suture (Text-fig. 17A) was prepared by etching, resulting in the disappearance of the small frills; the moderately deep L has about the same depth as E.

The probable microconchs are identical to the inner whorls of the macroconchs. Their adulthood is indicated not only by the approximation of the last septal suture and the egression of the body chamber as indicated by the impressed umbilical seam (Text-fig. 18) but also by the more acute angle of the chevrons.

Remarks. — Aguilera (in Castillo and Aguilera, 1895) figured two syntypes belonging to this species. The lectotype (here designated: *op. cit.*, pl. XXI, fig. 6; here, Pl. 39, fig. 4) is a more complete phragmocone with inner whorls, but crushed and covered with matrix on one side. The paralectotype (*op. cit.*, pl. XXI, fig. 4) is only a phragmocone fragment.

On account of the irregular, widely spaced blunt ribs with gently curved interspaces and the linguiform ventral chevrons, this species is clearly distinguished from all other species of *Kossmatia*. An examination by Verma of the fragmentary and distorted speci-

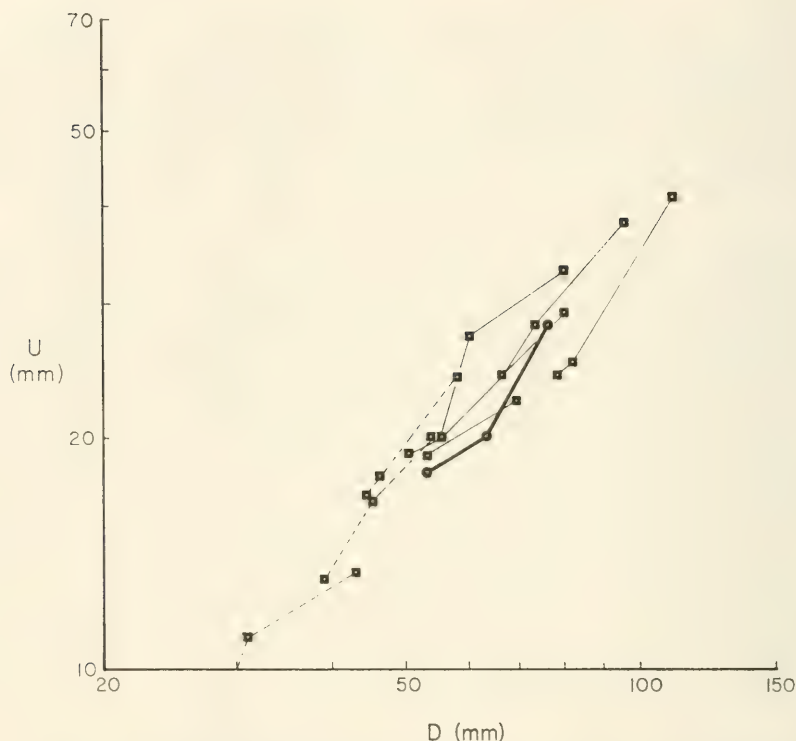


Text-figs. 17. — Septal sutures of *Kossmatia* spp., enlarged. A. *K. alamitosensis* (Aguilera), strongly "corroded", McM - J 1503/1, at H = 40.5 mm. B. *K. bifurcata* (Aguilera), McM - J 1517/8, at H = 62.5 mm. C. *K. exceptionalis* (Aguilera), McM - J 1526/28, at H = 54.5 mm.

men described as *K. aff. K. alamitosensis* by Imlay (1943, p. 542, pl. 95, fig. 3) from Chihuahua, has shown that it is distinguished by the more inflated subrectangular whorl section.

Occurrence. — El Verde Member, La Caja Formation, Sierra Catorce.

Age. — Upper Tithonian.



Text-fig. 18. — Scatter diagram of umbilical width (U) *vs.* diameter (D) for *Kossmatia alamosensis* (Aguilera) ♀ + ? ♂. The probable microconchs (dashed lines) are indistinguishable from the inner whorls of the macroconchs (continuous lines). The holotype is indicated by thicker lines.

Measurements (types and figured specimens only). —

	D	U	U/D	H	W	H/W	P/1/4 wh.	S/1/4 wh.	α
Lectotype	76.0	28.0	0.35	33.00	20.00	1.65	8	--	c. 45
	63.0	20.0	0.31	23.00	18.00	1.28	7	--	--
	c. 53.0	18.0	0.33	20.00	14.00	1.43	7	--	--
Paralectotype	--	--	--	34.0	26.0	1.30	--	--	--
McM - J 1526/14 (20 ¹)	--	--	--	18.0	15.5	1.16	7	13	42
- J 1526/16 (20 ¹)	54.0	20.0	c. 0.37	c. 23.0	--	--	7	--	--
	45.0	16.5	0.36	19.0	14.0	1.35	7	--	--
	39.0	13.0	0.33	15.0	13.0	1.15	6	--	--
- J 1526/26 (Q)	95.0	38.0	0.40	34.0	c. 29.0	c. 1.17	8	--	--
	73.0	28.0	0.38	30.0	23.0	1.30	7	--	--
	66.0	24.0	0.36	24.0	20.0	1.20	7	--	--
- J 1527D/3 (20 ¹)	58.0	24.0	0.41	21.0	19.0	1.10	7	13	48
	46.0	17.7	0.38	16.0	14.2	1.12	8	16	55
	44.0	16.8	0.38	14.0	13.8	1.01	7	14	62

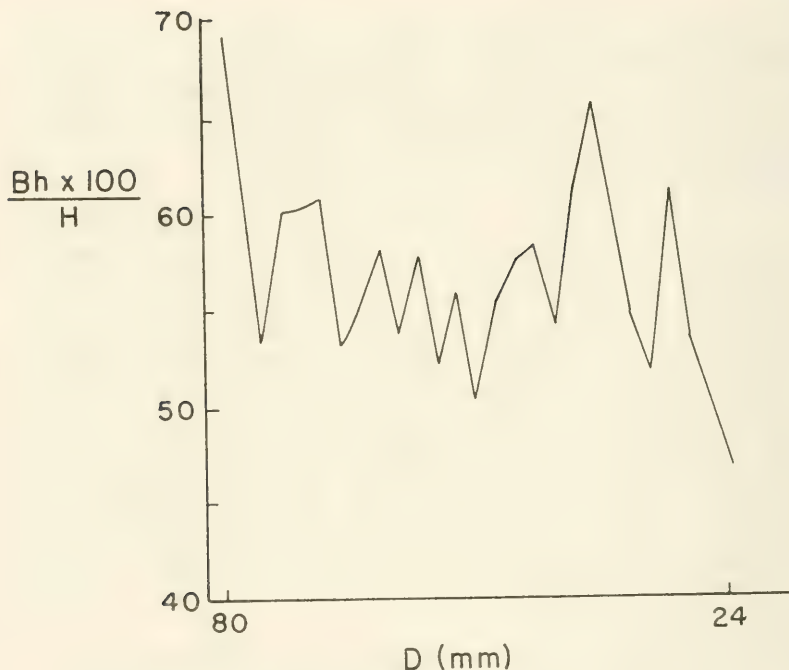
Kossmatia bifurcata (Aguilera), 1895 [♀ + ?♂]

Pl. 40, figs. 2-4; Pl. 41, figs. 1-2; Pl. 42, figs. 1-2; Text-figs. 16B, 17B, 19, 20
1895. *Hoplites bifurcatus* Aguilera in Castillo and Aguilera, Com. Geol. México, Bol. 1, p. 42, pl. XX, fig. 1.
?1895. *Hoplites mexicanus* Aguilera, *ibid.*, p. 41, pl. XV.
1895. *Hoplites*, sp., Aguilera, *ibid.*, p. 42, pl. XVIII.

Material. — Seventy to eighty specimens, mostly phragmocones of probable macroconchs, in various states of preservation; the following are best preserved and/or most complete: two from loc. 1A (McM - J 1494/26, 28); one from loc. 2 (McM - J 1495/2); one from loc. 10 (McM - J 1501/6); one from loc. 31 (McM - J 1510/3); three from loc. 32 (McM - J 1511/20, 87, 124); one from loc. 34 (McM - J 1513/2); one from loc. 19A (McM - J 1515/2); four from loc. 25 (McM - J 1517/6, 8, 62, 67); one from loc. 26 (McM - J 1518/1); and nine from loc. 14A (McM - J 1526/17, 19, 20, 22, 29, 30, 31, 32, 90). Only J 1511/87 and J 1517/6 are body chamber fragments, while J 1526/90 is complete with crushed body chamber. J 1494/26, 28 and J 1526/17, 19, 20, 22 are probably microconchs.

Description. — This is a large species of *Kossmatia*, several incomplete macroconchs attaining over 200 mm diameter; the estimated maximum diameter of the complete shell was about 250 mm. The largest microconch phragmocone has a diameter of about 70 mm.

The shell is planulate, compressed and moderately involute with rather narrow and shallow umbilicus. A scatter diagram of umbilical width *vs.* diameter of some of the better preserved specimens in the collection shows the range of variation and the position of the holotype (Text-fig. 20). The whorl section is compressed subrectangular throughout the phragmocone, about $1\frac{1}{2}$ times higher than wide (Text-fig. 16B). The flanks are almost flat and the venter is evenly rounded. The body chamber is poorly known. The inner whorls have usually sharp, rather dense irregular ribs which originate just above the umbilical seam, are rursiradiate on the umbilical shoulder, but soon assume a prorsiradiate, weakly flexuous course. The costation on the body chamber consists of more or less regular very stout ribs (c.15-17/ $\frac{1}{4}$ whorl); they are about 2-3 mm thick, 3-4 mm high and separated by 5-6 mm wide

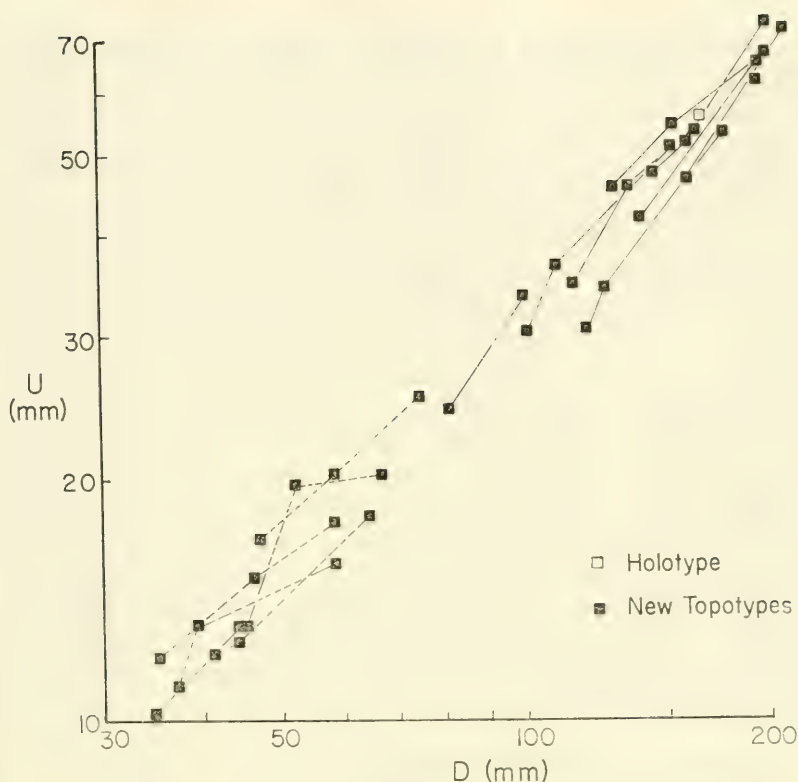


Text-fig. 19. — Ribbing of *Kossmatia bifurcata* (Aguilera). Plot of primary rib bifurcation height (Bh) as percentage of whorl height (H) vs. diameter (D); McM - J 1526/31, right side (with aperture downwards facing observer). Most ribs (assumed to be equidistant) bifurcate between 50-65% of H. Wh is subject to some error because of the difficulty in determining the exact point of bifurcation.

interspaces. On the internal mold, the ribs on the outer whorls may appear to be rather thin. The ribs on the inner whorls of some specimens are extremely dense. Thus, there is a good deal of infraspecific variation with regard to the thickness and density of ribs.

Most ribs bifurcate in a zone between 50% and 65% of whorl height (Text-fig. 19). Simple ribs are rare while intercalatories are seldom present. The secondaries are projected and chevron-like on the venter. On the body chamber, the ribs show less marked relief.

The phragmocone of the probable microconch closely resembles the phragmocone of the macroconch except for the smaller size (D c.50 vs. c.180 mm). The ribs on the outermost whorl are sharp and somewhat projected. Adulthood is indicated by approximation of septal sutures, egression of the body chamber, strong projection of the secondaries, and increasing acuteness of the chevrons.



Text-fig. 20. — Scatter diagram of umbilical width (U) *vs.* diameter (D) for *Kossmatia bifurcata* [♀ + ?♂]. The inner whorls of the macroconchs (continuous lines) cannot be measured without damaging the specimens, but it appears that they would fall within the range of variation of the microconchs (dashed lines).

The septal suture (Text-fig. 17B) shows a deep complicated E, a bipartite E/L saddle with deep incision, and a less deep trifid L; some of the complexity may have been lost during preparation with acid.

Remarks. — This species is clearly distinguished by its large size, the stout ribs of the outer whorls, and the consistency of bifurcation just above mid-flank. The variability in rib thickness and spacing and the absence of complete specimens appear to be the reason for the taxonomic “splitting” by Aguilera (*in* Castillo and Aguilera, 1895). Thus, his “*Kossmatia* sp.” is merely an advanced growth stage of *K. bifurcata*. This ontogenetic variability

is best illustrated by a phragmocone (McM - J 1526/90, Pl. 41, fig. 1) in which the ribbing changes from extremely fine to extremely coarse in the last $1\frac{1}{2}$ whorls. According to Aguilera (*op. cit.*, p. 41), *K. mexicana* is characterized by an alternation of simple and biplicate ribs. The incomplete holotype (monotypy) of *K. mexicana* is not among the collections in Mexico; a study of the plastotype at the U.S. National Museum (USNM 103299) showed that dimensionally it cannot be distinguished from *K. bifurcata* and that up to four successive ribs bifurcate, similar to *K. bifurcata*. We conclude that the mostly alternate biplication of *K. mexicana* appears to be merely a variation of the regular biplication found in *K. bifurcata*, and the two are therefore probably synonymous.

K. flexicostata (Aguilera) (see below) is more evolute and the densely ribbed stage persists longer in ontogeny. *K. varicostata* Imlay (1943, p. 539, pl. 92, figs. 1-4, pl. 93, fig. 1) somewhat resembles *K. bifurcata*, but the former has a wider umbilicus ($U/D = 0.44$, holotype USNM 193364) and different ribbing, changing from coarse on the early whorls, through dense on the middle whorls, to distant in the adult. The topotypes of *K. bifurcata*, figured here, are more and better preserved than the holotype, which is also refigured here (Pl. 42, fig. 1).

Measurements (figured specimens only). —

	D	U	U/D	H	W	H/W	P/ $\frac{1}{5}$ wh.	S/ $\frac{1}{4}$ wh.	a
Holotype ♀	165.0	55.0	0.33	c. 70.0	c. 35.0	2.0	c. 18	c. 24	--
" <i>Loplitres mexicanus</i> " Aguil. ♀	c. 225.0	c. 82.0		97.0	55.5		c. 20	c. 30	61
	c. 160.0	c. 58.0		75.0	49.5		c. 20	c. 26	61
	153.0	62.0		61.0	44.5		--	--	--
McM - J 1511/124, ?♂	44.0	13.0	0.29	19.0	13.0	1.46	13	25	62
	34.5	10.3	0.29	15.0	10.5	1.42	11	19	62
- J 1517/6 (body ch.) ♀	--	--	--	68.0	50.0	1.36	19	36	65
- J 1517/67 ♀	156.0	50.0	0.32	65.0	49.0	1.32	12	28	61
	110.0	36.0	0.32	47.0	40.0	1.17	14	28	60
	102.0	30.0	0.29	38.0	28.0	1.35	17	35	60
- J 1526/19, ?♂	58.0	17.5	0.30	c. 25.0	14.5	1.72	13	c. 17	c. 35
	46.0	15.0	0.32	18.5	13.0	1.42	8	c. 14	c. 45
	35.0	12.0	--	14.5	11.5	1.26	8	--	--
- J 1526/31 ♀	200.0	65.0	--	80.0	58.0	1.38	17	32	77
	c. 140.0	c. 41.0	--	c. 73.0	c. 44.0	1.65	--	--	78
- J 1526/90 ♀ (phrag. + body ch.)	176.0	52.5	0.34	72.5	c. 47.0	1.54	11	23	c. 65
	125.0	33.8	0.27	52.5	c. 39.0	1.34	13	--	--
	c. 120.0	32.0	0.26	50.0	c. 37.0	1.35	28	c. 55	c. 62

Occurrence. — El Verde Member, La Caja Formation, Sierra Catorce.

Age. — Upper Tithonian.

Kossmatia exceptionalis (Aguilera), 1895 [♀ + ♂] Pl. 43, fig. 1;
Pl. 44, fig. 2; Pl. 45, figs. 1-2; Pl. 46, figs. 1-2; Text-figs. 16C, 17C

1895. *Hoplites exceptionalis* Aguilera in Castillo and Aguilera, Com. Geol. México, Bol. 1, p. 43, pl. XX, fig. 2.

1895. *Rhacophyllites? alamosensis* Aguilera, *ibid.*, p. 15, pl. XIII, fig. 2 (non *Perisphinctes alamosensis* Aguilera, *op. cit.*, p. 30, pl. XXI, figs. 4, 6; = *Kossmatia alamosensis* Aguilera).

1895. *Rhacophyllites? disputabile*, Aguilera, *ibid.*, p. 14, pl. XIV.

Material. — Fifteen specimens, mostly incomplete phragmocones of macroconchs: ? one from loc. 1A (McM - J 1494/25); three from loc. 10 (McM - J 1501/?3, 5, 17); one from loc. 17 (McM - J 1502/1); one from loc. 22 (McM - J 1508/11); ? one from loc. 32 (McM - J 1511/1); one from loc. 19C (McM - J 1515B/1); one from loc. 3 (McM - J 1522/8); two from loc. 14A (McM - J 1526/27, 28); two from loc. 14D (McM - J 1527A/3, ?5); one from loc. 15 (McM - J 1535/6) and one from loc. 16 (McM - J 1536/16). J 1535/6 is the largest and J 1527A/3 a nearly complete phragmocone of the macroconch. J 1501/3, J 1494/25, J 1511/1 and J 1527A/5 are probably microconchs tentatively placed in this species.

Description. — This is a large species of *Kossmatia*, the largest macroconch phragmocone attaining 200 mm diameter. The shell is planulate, somewhat involute with about 25% whorl overlap. The whorl section is compressed subrectangular (Text-fig. 16C) almost twice as high as wide, with evenly rounded venter and subparallel to somewhat converging flanks. The umbilicus is rather narrow with almost vertical wall. The diagnostic feature is the densely ribbed ornamentation on the outer phragmocone whorl: the ultimate quarter whorl of large phragmocones bears about 32 closely spaced sharp ribs becoming less dense and thicker towards the aperture. The primaries are rursiradiate on the umbilical slope and gradually become prorsiradiate, weakly sinuous on the inner flank. At mid-flank they bifurcate or trifurcate; intercalatories are common and simple ribs occur occasionally. The remarkably regular secondaries are strongly projected and consistently moderately linguiform on

the venter, where the rib density is more than twice as high than that of the primaries.

The probable microconch resembles the inner whorls of the macroconch in whorl section and coiling. The thin, sharp ribs resemble those on the outer whorls of the macroconch, while the ribs on the inner whorls of the macroconch are more distant. Adulthood is indicated by septal approximation. The dimorphic relationship of the microconch is, therefore, somewhat questionable.

The septal suture (Text-fig. 17C) has a wide E, a slightly broader E/L saddle divided somewhat asymmetrically by an incision of moderate depth, a thin and very deep L, and three U lobes diminishing in depth towards the umbilical border.

Remarks. — A comparison with the several other large *Kossmatia* species shows that this species can be easily distinguished by its dense costation. The ribbing of *K. exceptionalis* is reminiscent of the densely ribbed intermediate growth stage of *K. varicostata* Im-lay (1943, p. 539, pl. 92, figs. 1-4, pl. 93, fig. 1); but in that species the rib density develops from a coarsely ribbed immature, through a densely ribbed intermediate, to a distantly ribbed adult stage. Moreover *K. varicostata* is more evolute.

"*Rhacophyllites? alamosensis*" Aguilera has slightly more convex flanks and a somewhat more narrowly rounded venter, while the density and style of ribbing are the same as in *K. exceptionalis* (its ribs appear to show less marked relief because the intercostal spaces are filled with matrix). Similarly "*Rhacophyllites? disputabile*" Aguilera is somewhat less densely ribbed but has a slightly more narrowly rounded venter. Both "*R.? alamosensis*" and "*R.? disputabilis*" are, therefore, considered conspecific with *K. exceptionalis*. The holotypes of both synonymous "species" are refigured here (Pl. 44, fig. 2; Pl. 45, fig. 1). Although the holotype of *K. exceptionalis* is an incomplete whorl fragment, it displays the diagnostic ornament better than the other type specimens, as judged by the new collections.

Occurrence. — El Verde Member, La Caja Formation, Sierra Catorce.

Age. — Upper Tithonian.

	D	U	U/D	H	W	H/W	P/ $\frac{1}{2}$ wh.	S/ $\frac{1}{2}$ wh.	a
Holotype ♀	--	--	--	67.0	c.44.0	1.52	18	43	50
" <u>Rhacophyllites</u> ? <u>alamitosensis</u> " Aguil. ♀	111.5	35.0	0.30	47.0	38.5	1.22	19	c.40	55
	c.85.0	21.0	0.24	38.0	30.0	1.26	--	--	45
" <u>Rhacophyllites</u> ? <u>disputabile</u> " Aguil. ♀	160.0	50.0	0.31	65.0	c.41.0	1.26	17	c.40	45
	c.120.0	c.45.0	0.37	52.0	36.0	1.44	22	--	--
McM - J 1501/3, ? ♂	51.0	20.0	0.39	21.9	14.8	1.47	16	--	--
- J 1501/5 ♀	--	--	--	45.0	35.0	1.28	c.30	c.75	c.57
- J 1502/1 ♀	--	--	--	70.0	44.0	1.59	24	--	c.56
	--	--	--	55.0	34.0	1.61	--	--	--
- J 1508/11 ♀	--	--	--	93.0	55.0	1.69	35	c.50	55
	--	--	--	74.0	45.0	1.64	--	--	57
- J 1511/1, ? ♂	23.0	5.5	0.24	10.0	9.0	1.11	11	--	--
- J 1515B/1 ♀	--	--	--	49.0	34.0	1.44	c.24	c.42	--
	--	--	--	44.0	31.0	1.41	--	--	--
- J 1522/8 ♀	--	--	--	48	34	1.41	24	--	--
- J 1526/28 ♀	--	--	--	52.0	31.0	1.67	25	42	61
	--	--	--	46.0	30.0	1.53	--	--	47
- J 1535/6 ♀	198.0	64.0	0.32	81.0	c.54.0	1.50	32	c.62	70
	160.0	51.0	0.31	70.0	43.0	1.62	32	c.64	63
	135.0	39.0	0.28	57.0	37.0	1.54	--	--	61
- J 1527A/3 ♀	146.0	40.0	0.27	64.0	44.0	1.45	26	44	65
	120.0	35.0	0.29	51.0	35.0	1.45	34	51	62
	90.0	25.0	0.27	42.0	27.0	1.55	--	--	--
- J 1527A/5, ? ♂	52.5	10.5	0.20	c.14.0	c.8.0	1.75	11	--	--

Kossmatia flexicostata (Aguilera), 1895 [♀ + ♂]

Pl. 44, fig. 1; Pl. 47, figs. 1-2; Text-fig. 16D

1895. *Perisphinctes flexicostatus* Aguilera in Castillo and Aguilera, Com. Geol. México, Bol. 1, p. 29, pl. XIII, fig. 1.?1906. *Perisphinctes santarosanus* Burckhardt, Inst. Geol. México, Bol. 23, p. 129, pl. XXXV, figs. 1-4.1912. *Kossmatia interrupta* Burckhardt, *ibid.*, Bol. 29, p. 134, pl. XXXIV, figs. 2, 3, 15 [? ♂].

Material.—Twelve specimens, mostly phragmocones or fragments of macroconchs: two from loc. 2 (McM - J 1495/1, 72); one from loc. 10 (McM - J 1501/18); one from loc. 17 (McM - J 1502/7); four from loc. 25 (McM - J 1517/7, 59, 63, 66); one from loc. 3 (McM - J 1522/5); one from loc. 14A (McM - J 1526/25); one from loc. 14D (McM - J 1527A/12); and one from loc. 15 (McM - J 1535/4). J 1517/59 is most probably an adult microconch phragmocone.

Description.—The shell of the phragmocone is planulate and rather evolute. The whorl section is compressed subrectangular, about $1\frac{1}{2}$ times higher than wide (Text-fig. 16D). The umbilicus is wide and shallow with a steep umbilical wall. The flanks are almost flat and the venter narrowly rounded. The shell carries irregularly spaced, dense and moderately sharp ribs which are rursiradiate on the umbilical wall and prorsiradiate on the flank. On the inner whorls, most ribs bifurcate or, more rarely, trifurcate. The outer whorls have also a few simple and intercalatory ribs. Branching takes place at about $2/3$ whorl height. The secondaries are strongly projected and form a chevron-like pattern on the venter.

The single probable microconch resembles the inner whorls of the macroconch and shows similar irregular spacing of the ribs. The specimen has approximated septa and the umbilical seam remaining of an egressing body chamber.

Remarks.—In whorl shape and coiling, our specimens are closely grouped around the holotype. *K. flexicostata* is distinguished from *K. bifurcata* (Aguilera) by greater compression, the more serpenticone coiling, and the irregularity of rib spacing. *K. exceptionalis* (Aguilera) is much more densely ribbed and more inflated. *K. interrupta* Burckhardt is nearly identical to our microconch in whorl shape, coiling and costation, and is placed in synonymy.

"*Perisphinctes*" *santarosanus* Burckhardt is similar to *K. flexicostata* except for the somewhat thinner ribs. *K. varicostata* Imlay (1943, p. 539, pl. 92, figs. 1-4; pl. 93, fig. 1) although similarly coiled, differs by predominantly densely ribbed inner whorls.

Occurrence. — El Verde Member, La Caja Formation, Sierra Catorce.

Age. — Upper Tithonian.

Measurements (figured specimens only). —

	H	D	H/D	h	W	h/s	P/ $\frac{1}{2}$ wh.	S/ $\frac{1}{4}$ wh.	α
Holotype ♀	c. 129.0	54.0	0.41	46.0	26.0	1.77	27	51	
	100.0	40.5	0.40	35.0	c. 26.0	1.54	25	44	40
McM - J 1517/7 ♀	140.0	53.5	0.38	53.0	32.0	1.65	18	35	55
	94.0	33.0	0.35	40.0	25.0	1.60	17	--	55
- J 1517/59 ♂	c. 70.0	c. 27.0	0.38	24.0	19.0	1.65	14	23	43
	c. 48.0	c. 16.0	0.33	21.0	17.0	1.23	14	--	45

***Kossmatia purisima* Verma and Westermann, n. sp.**

Pl. 47, figs. 3-6; Pl. 48, fig. 1; Text-figs. 16E, 21-24

?1895. *Hoplites calisto* var. Aguilera in Castillo and Aguilera, Com. Geol. México, Bol. 1, p. 38, pl. XXII, fig. 2 [*non* pl. XI, fig. 2, ? = *Substeuerocheras storrsi* (Stanton)].

?1912. *Kossmatia potosina* Burckhardt, Inst. Geol. México, Bol. 29, p. 132 [for above].

?1945. *Kossmatia kleinsorgensis* Anderson, Geol. Soc. America, Bull., vol. 56, p. 982, pl. 2, fig. 3 [*nom. dub.*; refigured by Imlay and Jones, 1970, U.S. Geol. Sur., Prof. Pap. 647-B, pl. 3, figs. 3-4].

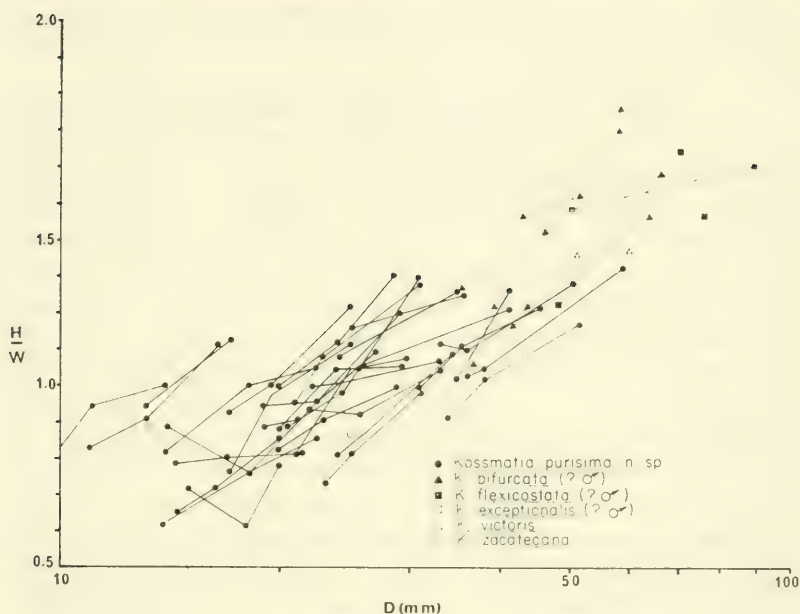
Holotype. — Specimen McM - J 1501/2, a well-preserved mature phragmocone, largest among specimens of this species.

Locus typicus. — Locality 10, about 500 m southwest of tunnel entrance, along old road from Santa Ana to Real de Catorce, Sierra Catorce.

Stratum typicum. — Upper part of El Verde Member, La Caja Formation.

Derivatio nominis. — After the abandoned mine La Purisima, south of "Radio Tower", east of Real de Catorce.

Diagnosis. — A small species of *Kossmatia* with subrectangular to subtrapezoidal whorl section; phragmocone moderately evolute;



Text-fig. 21. — Scatter diagram of 'compression ratio' (H/W) *vs.* diameter (D) for *Kossmatia purisima*, n. sp., along with the possible microconchs of other species. With regard to compression, *K. victoris* (Burckhardt) falls near the lower range of *K. purisima* while the probable microconchs of *K. bifurcata* (Aguilera), *K. flexicostata* (Aguilera), *K. exceptionalis* (Aguilera) and *K. zacatecana* Burckhardt generally are beyond the upper range of *K. purisima*; all of them differ from *K. purisima* by their ornament. The inner whorls of the macroconchs of *K. bifurcata*, *K. flexicostata* and *K. exceptionalis* are poorly known.

regularly spaced ribs of moderate density without marked change throughout the mature phragmocone; secondaries continuous on the venter with slight mid-ventral weakening, forming sharp chevrons.

Material. — Sixty specimens, mostly internal molds of phragmocones some of which are mature, well preserved: twenty-five from loc. 1A (McM - J 1494/1-24, 136); four from loc. 1B (McM - J 1494A/1-4); one from loc. 2 (McM - J 1495/66); three from loc. 10 (McM - J 1501/1, 2, 4); one from loc. 24 (McM J - 1509/1); one from loc. 32 (McM - J 1511/69); three from loc. 25 (McM - J 1517/45, 58, 60); four from loc. 3 (McM - J 1522/1, 2, 17, 18); one from loc. 11 (McM - J 1523/2); 13 from loc. 14A (McM -

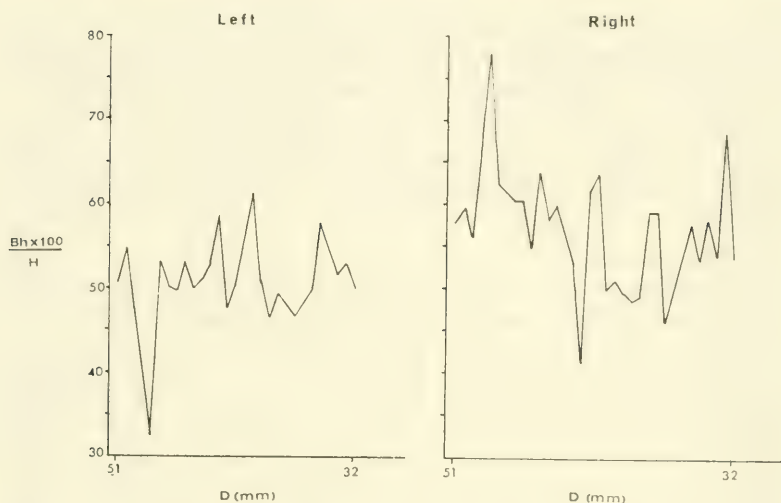
J 1526/1-8, 10, 13, 15, 21, 55); nine from loc. 14D (McM - J 1527A/1, 2, 4, 6-11); and one from loc. 15 (McM - J 1535/1). J 1527A/1 is at UNAM.

Description.—This small species (maximum phragmocone diameter 59 mm) is abundant in the El Verde Member of the La Caja Formation. The shell is planulate and moderately evolute. The inner whorls ($D = 15\text{--}30$ mm) are somewhat depressed elliptical in cross section ($H/W \leq 1.0$), while the outer whorls become subcircular to somewhat compressed ($H/W < 1.35$; Text-fig. 21). The outermost whorl of the phragmocone is moderately compressed subrectangular to subtrapezoidal with weakly rounded venter and steep umbilical wall. The ornament consists of regularly spaced ribs arising just beneath the umbilical shoulder. From rursiradiate on the umbilical shoulder, the ribs become rectiradiate and bifurcate at about mid-flank (Text-fig. 22); intercalatories and trifurcating ribs are rare. At the venter, the secondaries are strongly projected forming chevrons. Some weakening of the ribs occurs at mid venter. The number of primaries, usually 7-10 per quarter whorl, does not appreciably change throughout the phragmocone. The body chamber is not preserved on any of the specimens.

The septal suture has a deep E, a somewhat less deep L, and two small U lobes. Some of the large specimens show a tendency towards terminal septal approximation and there is evidence of egression of the body chamber from remnants of the umbilical seam. The ontogenetic development of the septal suture is illustrated (Text-fig. 23).

Remarks.—The small species here named *K. purisima* occur in association with *Kossmatia bifurcata* [♀ + ?♂], *K. exceptionalis* [♀ + ?♂], *K. alamosensis* [♀ + ?♂], and *K. flexicostata* [♀ + ?♂]. It is much smaller than the macroconchs of these species and resembles their probable microconchs in diameter, whorl section and coiling but differs in the ornament. While there is some resemblance to the dimensionally poorly known inner whorls of the macroconchs listed above, most specimens clearly differ by their much smaller size. They also have a subtrapezoidal whorl section and thinner, evenly spaced ribs.

The ribbing of *Kossmatia purisima* closely resembles that of *K. richteri* (Oppel), but the latter is easily distinguished by the



Text-fig. 22. — Ribbing of *Kossmatia purisima*, n. sp. Plot of primary ribs bifurcation height (Bh) as percentage of whorl height (H) vs. diameter (D), for McM - J 1501/2, left and right sides (aperture facing downwards facing observer). Most ribs (assumed to be equidistant) bifurcate in a zone between 45-65%. Lows on the left side roughly correspond to the highs on the right side. Bh is subject to some error because of the difficulty in determining the exact point of bifurcation.

much more compressed whorl section (H/W 2.37-2.66 vs. < 1.35). *K. victoris* Burckhardt is close to the upper range of our species in whorl compression, but does not possess a subtrapezoidal section and is more evolute (U/D 0.43 vs. 0.28-0.35) (Text-fig. 24). The whorl section of *K. zacatecana* Burckhardt ($H/W = 0.72-0.86$) falls within the lower range of variation of our species (Text-fig. 21) but it is more evolute ($U/D = 0.44$) (Text-fig. 24). *K. interrupta* Burckhardt is much more compressed ($H/W = 1.43$ at 76 mm D) and much more evolute ($U/D = 0.46$). The microconchs of *K. bifurcata*, *K. mexicana* and *K. densicostata* fall within the upper range of variation of *K. purisima* (Text-figs. 21, 24) but they are distinguished by the density and style of ribbing.

The smaller specimen of "*Hoplites calisto* var." of Aguilera (pl. XXII, fig. 2) from Sierra Catorce was renamed by Burckhardt

(1912, p. 132) as *K. potosina* and included in his list of *Kossmatia* species. However, he did not give any reasons for doing so, nor did he redescribe or illustrate the type specimen which now can not be found in the collection. Measurements taken from the poor illustration of the lateral view indicate that this species has the same degree of involution as *Kossmatia purissima*. However, according to Aguilera's description, his form has frequent triplicate ribs which are rare in our species.

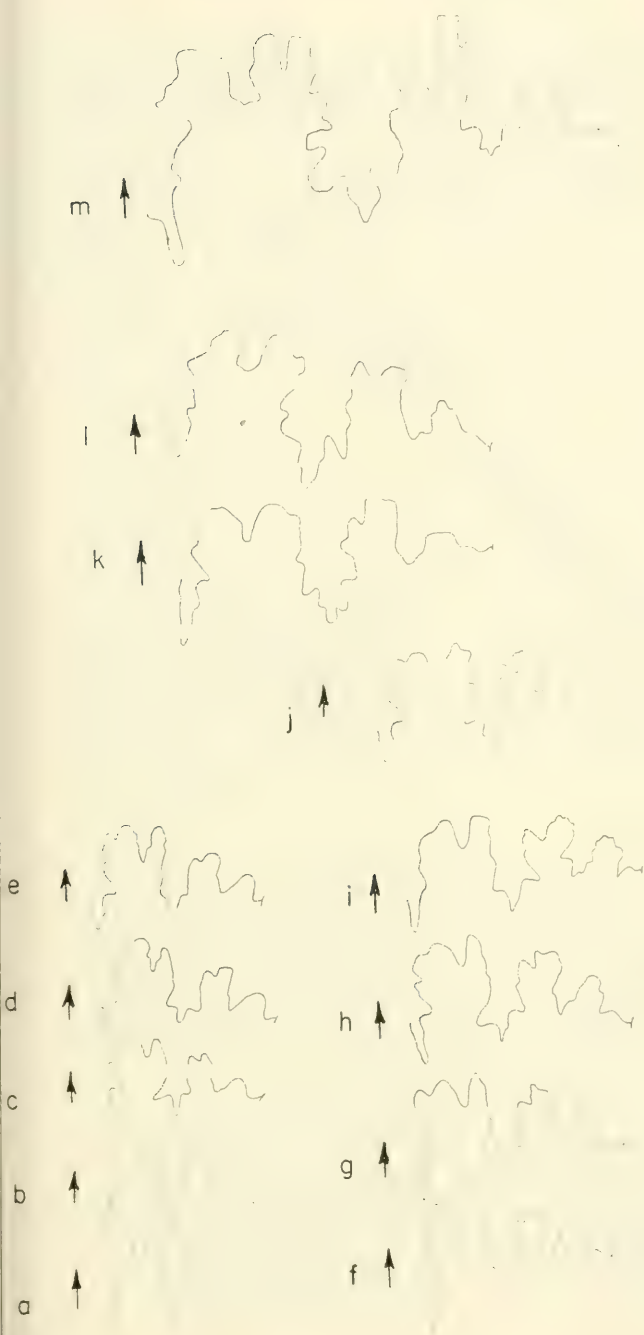
Kossmatia kleinsorgensis Anderson (1945) from California appears to be somewhat similar to our species. However, *K. kleinsorgensis* is here considered as a *nomen dubium* because of the fragmentary nature of the type material. *K. tehamaensis* Anderson (1945, p. 981, pl. 2, figs. 1a-c; refigured by Imlay and Jones, 1970, p. B31, pl. 3, figs. 1, 2) has more predominant and irregular ribs, a marked ventral groove, and is more involute. *K. dilleri* (Stanton) (1896, p. 82, pl. 18, figs. 6, 7; refigured by Imlay and Jones, 1970, p. B30, pl. 3, figs. 5-7) is more evolute and has an almost round whorl section.

Occurrence. — El Verde Member of La Caja Formation, Sierra Catorce.

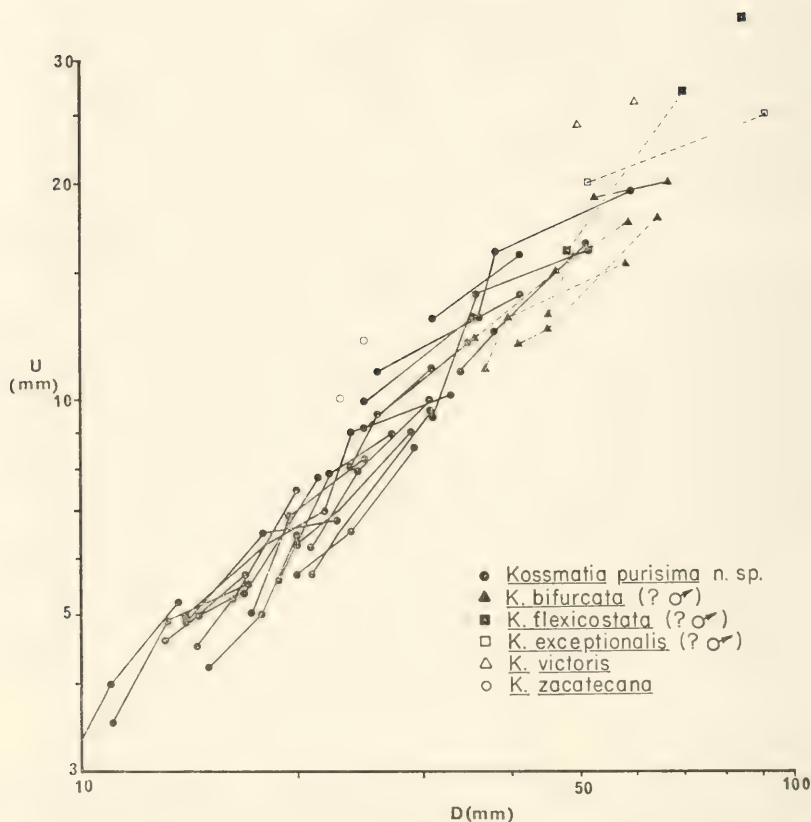
Age. — Upper Tithonian.

Measurements (figured specimens only). —

	D	U	U/D	H	W	H/W	P/¼ wh.	S/¼ wh.	α
Holotype	51.0	16.5	0.32	22.7	19.3	1.17	13	25	57
	38.0	12.8	0.33	14.6	14.2	1.02	10	19	55
	34.0	11.0	0.32	12.5	13.5	0.92	11	24	62
McM - J 1494/4	22.5	7.5	0.33	10.0	11.6	0.86	8	19	68
	18.5	6.5	0.35	7.0	9.0	0.77	7	15	72
	13.8	4.9	0.35	5.0	8.0	0.62	7	15	c.85
- J 1494/6	27.2	9.0	0.33	11.0	10.0	1.10	10	20	61
	22.4	7.9	0.35	8.0	8.3	0.96	10	22	67
	19.0	5.6	0.29	7.0	7.3	0.95	9	20	65
- J 1494/12	29.4	8.5	0.28	12.5	10.8	1.15	10	20	62
	23.8	6.5	0.37	11.0	10.5	1.04	7	18	61
	20.0	5.7	0.28	7.4	8.4	0.88	8	20	c.68
- J 1526/10	32.5	10.8	0.33	15.5	11.5	1.34	6	15	62
	25.0	7.8	0.31	10.5	10.3	1.01	6	17	c.60
	21.0	6.2	0.29	9.0	9.9	0.91	5	13	58



Text-fig. 23. — Ontogeny of the septal suture of *Kossmatia purissima*, n. sp. a-j, McM - J 1495/66, ten successive sutures from $H = 3.7$ mm to 6.5 mm; k-m, McM - J 1523/2, k at $H = 7.1$ mm, l at $H = 8$ mm, m at $H = 9.7$ mm. Note the appearance of a new umbilical lobe or partial lobe in c.



Text-fig. 24. — Scatter diagram of umbilical width (U) *vs.* diameter (D) for *Kossmatia purisima* n. sp., along with the possible microconchs of other species. *K. victoris* (Burckhardt) and *K. zacatecana* (Burckhardt) appear to fall outside the range of *K. purisima*, while the probable microconchs of *K. bifurcata* (Aguilera), *K. flexicostata* (Aguilera), and *K. exceptionalis* (Aguilera) fall near or outside the upper range; all of them differ from *K. purisima* by their ornament. The inner whorls of the macroconchs of *K. bifurcata*, *K. flexicostata* and *K. exceptionalis* are poorly known.

Genus **SUBSTEUEROCERAS** Spath, 1923

[Syn.: (?) *Parodontoceras* Spath, 1923; see below under comparison.]

Type Species: *Odontoceras koeneni* Steuer, 1897.

Historical Review. — Spath (in Trechmann, 1923, p. 308), in an appendix to Trechmann's description of the Jurassic rocks of New Zealand, introduced the genus *Substeueroeras* together with

eight other new genera. He designated the type species but included no generic diagnoses. Spath also frequently gave new generic and specific names to figures of specimens only. In the words of Cox (1957): "no author had previously founded so many new genera and species in so few words". Since 1931, however, the International Rules of Zoological Nomenclature require a verbal diagnosis for the validation of a new genus.

The type species designated by Spath, *Odontoceras koeneni* Steuer from the Tithonian-Berriasian of Argentina, appears to be the best starting point for a discussion of the genus. A summarized description translated from the Spanish version of Steuer's (1897) paper is as follows:

The shell is composed of rapidly growing whorls, higher than wide, 1/3rd involute. The umbilicus is wide. The whorl section is rectangular with corners rounded off, and the sides somewhat arched. The primary ribs are thin and low, 50-70 in number; they originate on the umbilical wall, are first directed backward, soon bend forward and run in a falciform curve over the flanks. The division of the ribs is irregular; the majority bifurcate, others remain simple and still others, particularly in the adult stage, bifurcate in three or rarely four branches. The bifurcation occurs generally in the middle of the flanks. In the young stage the ribs are interrupted by a smooth band along the venter but at a later stage they cross the venter without interruption although somewhat weakened. On the body chamber, the ribs are distant, broader and lower and appear to be completely lost towards the extremity. The suture line has an external bifurcate lobe and a somewhat longer, almost symmetrically branched lateral lobe. All the saddles are wide. The external saddle is 1-1/2 times wider than the first lateral lobe, and is divided into two unequal parts by a secondary lobe.

Most of the species attributed to *Substeueroceras* occur in Argentina and Mexico, although isolated occurrences have also been reported from Europe, Iraq, and Japan.

Besides *S. koeneni*, the following five "species" now placed in *Substeueroceras* were described by Steuer (1897) from the same region of Argentina (the descriptions are available to us in the Spanish translation of 1921 which contains identical plates):

Odontoceras permulticostatum (pl. XXIII, figs. 1-2; 1921, p. 84, same pl. & figs.)

O. fasciatum (pl. XVII, figs. 1-3; 1921, p. 74, same pl. & figs.)

O. subfasciatum (pl. XIX, figs. 1-3; 1921, p. 75, same pl. & figs.)

O. intercostatum (pl. XXII, figs. 1-5; 1921, p. 74, same pl. & figs.)

O. ellipsostomum (pl. XXI, figs. 1-2, pl. XXII, fig. 12; 1921, p. 78, same pls. & figs.)

Of the above, *S. permulticostatum* and *S. fasciatum* are hardly distinguishable from each other and from *S. koeneni*. All are tabulate shells covered with irregularly branching and prorsiradiate flexuous ribs, differing only in grades of rib density. They are, therefore, here synonymized with *S. koeneni*. *S. subfasciatum* and *S. intercostatum* resemble each other but differ from *S. koeneni* by somewhat coarser primaries. However, the thickness of the primaries varies considerably within a single species. Thus the last quarter of the outer whorl of *S. koeneni* displays ribbing which is nearly identical with that of the outer half whorl of *S. intercostatum*. It appears, therefore, that *S. intercostatum* and *S. subfasciatum* are probably also synonymous with *S. koeneni*. *S. ellipsostratum* differs from the rest by its larger size ($D = 234$ mm) and the more evolute outer whorl ($U/D = 0.44$ vs. $= 0.30$); the ribs are weakly prorsiradiate. Thus Steuer's six "species" can easily be reduced to about two.

"*Reineckeia*" *striolatifima* Steuer, 1897 (1921, p. 63, pl. XIV, figs. 5-7) was placed in *Substeueroceras* by Gerth (1925, p. 85) and Leanza (1945, pl. I, figs. 2, 7, 9, 12, 13). The well-rounded venter and the dense, almost straight, unbranched ribs make this classification doubtful.

Leanza (1945), while describing the Tithonian fauna of Mendoza Province, identified *S. koeneni* and added the two new species "*S.*" *disputible* (p. 29, pl. VII, figs. 3; pl. VIII, fig. 3; pl. IX, fig. 1) and *S. extans* (p. 30, pl. VII, figs. 1-2). "*S.*" *disputible* does not belong in this genus because of the extremely coarse, almost bullae-like primaries, the intercalation of the secondaries, and the much wider umbilicus ($U/D = 0.48$); it could probably be transferred to *Argentiniceras* Spath.

From the Jurassic-Cretaceous boundary of San Pedro del Gallo, Mexico, Burckhardt (1912) named "*Steueroceras durangense*" (p. 169, pl. XL, figs. 5, 7-10) and "*S. lamellicostatum*" (p. 167, pl. XL, figs. 1-4, 6) which Imlay (1939, table 9) correctly transferred to *Substeueroceras*. Both should be regarded as *nomina dubia* since they are based on fragmentary specimens; their specific distinction from *S. koeneni* is doubtful. Burckhardt (*op. cit.*) also described several other fragments of *Substeueroceras* from the same beds un-

der "*Steueroceras* sp. ind." (p. 170, p. XXXIX, fig. 11; p. 170, pl. XLI, figs. 1-4; p. 171, pl. XL, figs. 11-15; 1919-21, p. 57, pl. XX, figs. 4-9; p. 58, pl. XXI, figs. 1-2). Indeed, his entire material is too fragmentary to justify comments on specific affinities.

Imlay (1939, table 9) placed the Sierra Catorce species "*Perisphinctes*" *alamitosensis* and "*Hoplites*" *exceptionalis*, Aguilera spp., in *Substeueroceras*. Both have strong ventral arching of the ribs which in our opinion is a diagnostic attribute of *Kossmatia* (see above). "*Perisphinctes*" *santarosanus* Burckhardt (1906, p. 129, pl. XXXV, figs. 1-4), later correctly placed in *Kossmatia* by its author (Burckhardt, 1912), shows the same ventral feature and we cannot follow Imlay (1939, table 9) who also transferred this species to *Substeueroceras*.

From the La Casita Formation of Sierra de Jimulco, Coahuila, Imlay (1939) described the three new species *Substeueroceras kellumi* (p. 50, pl. 14, figs. 1-4), *S. subquadratum* (p. 49, pl. 15, figs. 8, 12-15), and *S. alticostatum* (p. 51, pl. 15, figs. 1-7). Through the courtesy of the Museum of Paleontology, University of Michigan at Ann Arbor, we were able to examine the material and confirm the generic affinity with *Substeueroceras*. *S. kellumi* has almost the same density and style of ribbing as *S. koeneni* and the somewhat greater involution suggests that it is a geographic subspecies of *S. koeneni*. The specimen described as *S. n. sp. aff. S. subfasciatum* (Steuer) by Imlay (1939, p. 50, pl. 15, fig. 9) appears to be a distorted *S. kellumi*.

Peña (1964) introduced "*S. durangoense*" for a single incomplete distorted specimen from the Tithonian of Durango, Mexico. Likewise, "*Substeueroceras? imlayi*" of Cantu Chapa (1963, p. 40, pl. III, fig. 3) from the Tithonian of Nuevo Leon is known in one incomplete fragment only. Both are regarded as *nomina dubia*.

From northwestern California, Anderson (1945) named *S. stan-toni* (p. 982, pl. 11, figs. 3, 4; pl. 15, fig. 3; refigured by Imlay and Jones, 1970, p. B42, pl. 10, figs. 11-18). We agree with the generic assignment of this species.

In Europe, *Substeueroceras* appears to be much less common and diverse than in the Americas. *Ammonites carpathicus* Zittel (1868, p. 107, pl. 18, figs. 4, 5) appears to be the only well-known

species. Perhaps some French forms described under *Berriasella* by Mazenot (1939) would better be placed in *Substeuerocheras*.

Spath (1950) recorded several unnamed species of supposed *Substeuerocheras* from "bed j" of the Upper Jurassic succession on Jabel Gara, northern Iraq. Although he intended to publish descriptions separately (1950, p. 97), to our knowledge, these have not appeared.

Sato (1962, p. 96, pl. 4, figs. 8-10) reported *Substeuerocheras* sp. from the Kogoshio and Kitakami formations of Japan and named the topmost "niveau" of the Tithonian after this genus (Sato, 1964, pp. 888, 896). However, no other description of *Substeuerocheras* from Japan has been published.

Diagnosis of Substeuerocheras. (Based on the described species from Argentina and Mexico, and our material from Sierra Catorce.) —

A genus of *Berriasellinae* comprising planulate, somewhat evolute forms with flat to weakly convex flanks and more or less tabulate venter. The moderately to extremely dense irregular and slightly flexuous ribs bifurcate at different heights; secondaries weakly projected crossing straight over the venter.

Description. — *Substeuerocheras* comprises species of moderate dimensions, most commonly 100-200 mm in diameter. The shell is flattened planulate, with subrectangular whorl section that is only slightly higher than wide in the outer whorls. The inner whorls may be subquadratic or depressed subrectangular. Most species are moderately evolute with umbilical width of about 30-40% of the diameter. The flanks are flat, parallel to subparallel; feebly convex flanks are rare. The venter is convex on the inner whorls but essentially flat on the outer whorls with distinct shoulders. The umbilicus is shallow to moderately deep. The umbilical wall is consistently vertical or almost vertical with sharp umbilical shoulder.

The ornament consists of ribs only; constrictions and tubercles are absent. The ribbing is generally fine and dense although some species may also have somewhat distant and coarse ribs. Originating at the umbilical seam or just above it, the ribs are at first directed backward but bend forward on the umbilical shoulder, continue weakly sinuous rectiradiate on the flanks, and project feebly on the shoulder. They cross the venter without any significant arching al-

though a weak curvature may be present in some species. In the immature whorls and internal molds of mature whorls, a weakening of the ribs takes place in the siphonal region.

The branching of ribs is characterized by marked irregularity both in type and location. Most ribs are biplicate, some are simple, and others are triplicate. The location of branching fluctuates irregularly from near the umbilical shoulder to near the ventral shoulder. On the body chamber of some species the ribs become distant, while on others they become obsolete towards the aperture.

The septal suture which has been studied only in a few cases, is as in other *Berriasellinae*: E is wide; L is trifid, about $1\frac{1}{2}$ times deeper than E; the U lobes decrease in depth towards the umbilical seam; the E/L saddle is asymmetrical, bipartite with a moderately deep incision.

Comparison.—*Substeueroceras* is associated with *Kossmatia* with which it shows some obvious similarities; both are compressed planulates with coarse to dense branched ribbing. However, there are some important differences between the two genera. (1) The venter in *Kossmatia* is generally more rounded. (2) In *Kossmatia*, rib bifurcation occurs regularly above mid-flank, while the ribs of most *Substeueroceras* are more flexuous and irregular in mode and location of branching. (3) In general, *Substeueroceras* shows finer ribbing than *Kossmatia*. (4) The diagnostic distinction is the ventral disposition of the ribs; in all *Kossmatia*, especially in the adult stage of both dimorphs, the ribs form a moderate to strong linguiform sinus in the form of orad convex rounded chevrons, while in *Substeueroceras* the ribs cross the venter without significant curvature.

The distinction between *Substeueroceras* and "*Parodontoceras*" Spath, however, is not as clearly marked, because ventral arching of the ribs is missing in both. According to Imlay and Jones (1970), the inner whorls of *Parodontoceras* have constrictions which are absent in *Substeueroceras* and a deeper and more conspicuous ventral groove; the outer whorls have more prominent ribs which are more regularly biplicate and lack sinuosity, while there is branching at different height in *Substeueroceras*. In reality, the above mentioned differences are subtle and can be observed only in material contain-

ing well-preserved inner and outer whorls. High variation in rib density, "stiffness", and branching as well as ventral grooving or rib interruption occurs in both alleged genera at specific levels (cf. *S. koeneni* in Leanza, 1945). The constrictions reportedly characterizing the inner whorls of "*Parodontoceras*" are not observed by us even in "*Parodontoceras*" *storrzi* (Stanton) which was refigured and redescribed by Imlay (1970, p. B44). Therefore, we do not believe that a separation even at subgeneric level would be useful or reflect natural relationships, and both names are synonymized. The better known of the two equally old names, *Substeueroceras*, is retained.

Age. — All authors agree that *Substeueroceras* appears at the top of the Tithonian and may continue well into the Berriasian. The Upper Tithonian age for the occurrences in Mexico is substantiated by association with *Kossmatia*. In the Sierra Catorce, *Substeueroceras* occurs only in the uppermost part of the La Caja Formation.

***Substeueroceras alticostatum* Imlay, 1939**

Pl. 48, figs. 2-4

1939. *Substeueroceras alticostatum* Imlay, Geol. Soc. America, Bull. 50, p. 51, pl. 15, figs. 1-7.

Material. — Nine internal molds of phragmocones: three from loc. 32 (McM - J 1511/81, 84, 297); one from loc. 34 (McM - J 1513/111); one from loc. 30 (McM - J 1516/2); one from loc. 25 (McM - J 1517/71); one from loc. 15 (McM - J 1535/2); and two from loc. 16 (McM - J 1536/6, 7). Most specimens are laterally compressed and all except one have one side covered with firmly cemented matrix. Three specimens bear numerous casts of serpulids distributed randomly on the surface of the shell. Many serpulids have grown in the direction of coiling of the ammonite and probably were true epizoans.

Description. — The shell is planulate and evolute. Partial crushing has altered the whorl section of most specimens from subquadrate to compressed rectangular. The umbilicus is somewhat narrow and deep with steep wall and rounded shoulder.

The inner and outer whorls have high narrow ribs, which arise at the umbilical seam and follow a typical *Substeueroceras* pattern;

the majority of the ribs bifurcate at irregular height on the flank averaging about mid-flank and are weakly sinuous, while intercalatories and simple ribs occur here and there; all ribs cross the venter transversely without inflexion and only slight weakening. A true mid-ventral furrow is missing in all specimens.

Remarks. — Imlay (1939, p. 52) compared this species with "*Steuroceras santaros anum*" Burckhardt and "*Rhacophyllites? disputabile*" Aguilera. Both are, however, here placed in *Kossmatia* because of the strong ventral arching of the ribs. Leanza's specimen of *Substeuroceras koeneni* (Steuer) (Leanza, 1945, pl. V, figs. 7, 8), although resembling *S. alticostatum*, has a conspicuous mid-ventral groove. *S. alticostatum* differs from *S. subquadratum* Imlay (1939, pl. 15, figs. 8, 12-15) in the more compressed whorl section and the coarser ribbing.

Occurrence. — El Verde Member, La Caja Formation, Sierra Catorce.

Age. — Upper Tithonian.

Measurements (type and figured specimens only.) —

	D	U	U/D	H	W	H/W	P/¼ wh.	S/¼ wh.
Holotype	43.00	13.00	0.30	18.5	17.5	1.05	11	21
	33.0	9.0	0.27	15.0	16.0	0.93	11	21
	27.0	7.0	0.25	12.0	12.0	1.00	—	—
Paratype (UM 20055)	c.62.0	c.25.0	0.40	c.24.0	c.15.0	1.60	13	26
	c.40.0	c.14.0	0.35	15.0	13.0	1.15	10	19
	c.38.0	c.16.0	0.42	c.13.0	c.12.0	1.08	10	17
Paratype (UM 20086)	42.0	10.0	0.23	21.5	14.5	1.48	10	17
	34.0	10.0	0.29	14.5	13.5	1.07	10	20
	28.0	7.0	0.25	12.0	12.5	0.96	9	17
McM - J 1511/297	c.71.00	c.23.00	0.32	c.30.00	c.19.00	1.57	15	31
	c.52.00	c.17.00	0.32	c.21.00	c.18.00	1.16	13	—
- J 1517/71	—	—	—	24.0	c.19.0	1.26	11	22
- J 1536/7	c.55.00	c.17.00	0.30	c.24.00	c.17.00	1.41	c.14	—
	c.42.00	c.13.00	0.30	c.20.00	c.14.00	1.42	c.13	—

Substeuroceras storrsi (Stanton), 1896 Pl. 51, figs. 1-2; Text-fig. 26

1896. *Hoplites storrsi* Stanton, U.S. Geol. Sur., Bull. 133, p. 79, 80, pl. 17, figs. 1, 2; pl. 18, fig. 3.

1970. *Parodontoceras storrsi* (Stanton), Imlay and Jones, U.S. Geol. Sur., Prof. Paper 647-B, p. 44, pl. 12, figs. 11, 16-18.

Material. — Ten internal molds of phragmocones, some rather ill preserved: four from loc. 32 (McM - J 1511/26, 53, 54, 68); one from loc. 25 (McM - J 1517/69); four from loc. 16 (McM - J 1536/3, 4, 10, 31); and one from loc. 20B (McM - J 1538A/1).

Description. — The shell is compressed planulate, moderately involute. The whorl section is compressed subrectangular, about $1\frac{1}{2}$ times higher than wide (Text-fig. 26). The flanks are nearly parallel, the venter is gently rounded to flat, and the umbilicus moderately shallow with steep wall. The inner whorls have fine flexuous ribs and shallow constrictions which are conspicuous in some specimens but can be detected only in oblique light in others. The outer whorls bear coarse flexuous ribs which arise at the middle of the umbilical wall, are rursiradiate on the umbilical shoulder, and become flexuous rectiradiate on the flanks. Biplication occurs at about mid-flank. The secondaries are weakly projected and cross uninterrupted over the venter. On the immature specimens, a slight mid-ventral weakening of the ribs may be present.

Remarks. — An examination of the holotype of *P. storrsi* in the United States National Museum by Verma has confirmed the identity of our specimens. Aguilera (in Castillo and Aguilera, 1895) described two different specimens from Sierra Catorce under the name *Hoplites calisto* (d'Orbigny) var. (pl. XI, fig. 2, pl. XXII, fig. 2), the second of which may be identical with *Kossmatia purissima*, n. sp. Stanton (1895, p. 80) placed the first specimen in "*Hoplites*" *storrsi*, an identification tentatively accepted by Burckhardt (1930, p. 80). The new material confirms the occurrence of *P. storrsi* in the Sierra Catorce. Aguilera's specimens are missing, but, judging from the original description and illustration, the first specimen appears to be somewhat more evolute than Stanton's and our specimens. Imlay and Jones (1970, p. B44) have already noted the affinities of "*Parodontoceras*" *storrsi* to the Argentinian "*P.*" *calistoides* (Behrendsen) as well as to the Californian "*P.*" *reedi* (Anderson) (1945, p. 978, pl. 6, fig. 10, pl. 7, fig. 3) and other species of "*Parodontoceras*".

Occurrence. — El Verde Member, La Caja Formation, Sierra Catorce.

Age. — Upper Tithonian.

Measurements (type and figured specimens only). —

	D	U	U/D	H	W	H/W	P/¼ wh.	S/¼ wh.
Holotype	110.0	35.0	0.31	48.0	30.0	1.60	15	30
McM - J 1536/3	105.0	34.0	0.32	42.0	29.0	1.44	10	21
- J 1538A/1	58.0	20.0	0.34	23.0	c.16.5	1.39	10	24

Substeuerocheras catorcense Verma and Westermann, n. sp. [♀ + ?♂]
Pl. 49, figs. 3-4; Pl. 50, figs. 1-2; Text-fig. 25

?1945. *Substeuerocheras stantoni* Anderson, Geol. Soc. America Bull. 56, p. 982, pl. 2, figs. 3, 4; pl. 15, fig. 3 (refigured by Imlay and Jones, 1970, p. B42, pl. 10, figs. 11-18) [? ♂; *nom. dub.*].

Holotype. — McM - J 1510/4, a well-preserved mature macroconch phragmocone, covered on one side with matrix.

Allotype. — McM - J 1511/3, a well-preserved phragmocone of a probable microconch slightly damaged on the venter, from loc. 32 (Cieniguita).

Paratypes. — (1) McM - J 1511/19, a well-preserved incomplete phragmocone; (2) McM - J 1511/50, a weathered phragmocone, showing several septal sutures. Both from loc. 32 (Cieniguita).

Locus typicus. — Locality 31, hill slope northeast of Cieniguita, about 7 km southeast of Real de Catorce, Sierra Catorce.

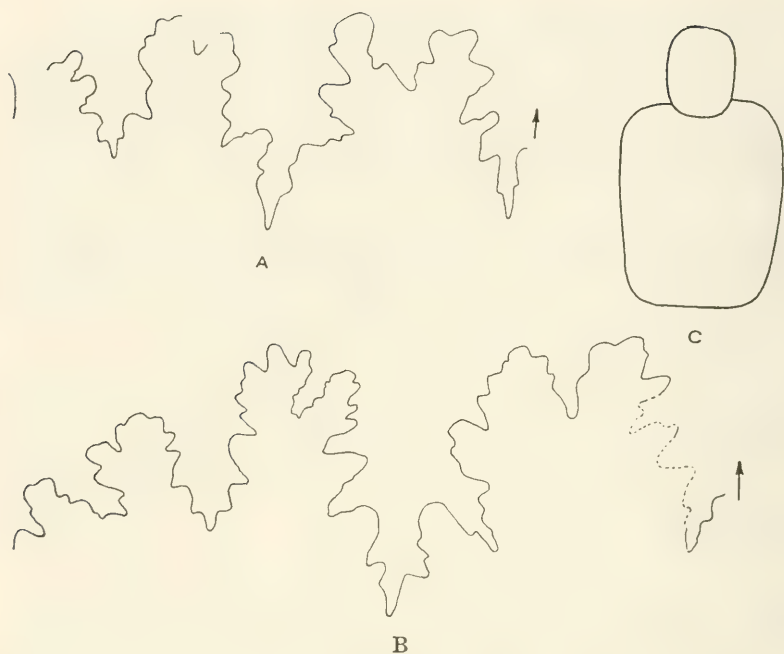
Stratum typicum. — El Verde Member, La Caja Formation.

Derivatio nominis. — After the Sierra Catorce.

Age. — Upper Tithonian.

Diagnosis. — A large species of *Substeuerocheras* with fine ribs of moderate density on the inner whorls and stout distant ribs on the outer whorls; primaries with strong rursiradial inflexion on umbilical shoulder; secondaries traversing the venter straight without marked reduction.

Material. — Several dozen specimens, mostly macroconchs, including the following more complete or better preserved: one from loc. 18 (McM - J 1503/2); two from loc. 21 (McM - J 1504/3, 11); five from loc. 22 (McM - J 1508/62, 77, 80, 100, 101); the holotype from loc. 31 (McM - J 1510/4); twelve from loc. 32 (McM - J 1511/3, 6, 9, 10, 12, 14, 16, 17, 19, 22, 50, 86); two from loc. 19A (McM - J 1515/1, 3); two from loc. 19D (McM - J 1515C/1, 2); one from loc. 25 (McM - J 1517/70); one from loc. 14A (McM -



Text-fig. 25. — Septal sutures and whorl section of *Substeuroceras catorcense*, n. sp. A. Microconch [♂], McM - J 1511/3, at H = 17 mm. B. Macroconch (♀), McM - J 1510/4, at H = 38 mm. C. Macroconch (♀) phragmocone, McM - J 1511/19, $\times 0.5$.



Text-fig. 26. — Cross section through the phragmocone of *Substeuroceras storrsi* (Stanton), McM - J 1536/3, $\times 0.5$.

J 1526/86); one from loc. 14G (McM - J 1527D/4); one from loc. 20A (McM - J 1538/1) and one from loc. 20B (McM - J 1538A/2). Specimens J 1508/62, 100, J 1511/3, 6, 9, 10, 12, 14, 16, 22, J 1515/3 and J 1538A/2 appear to be microconchs. J 1515C/2 is at UNAM.

Description. — The diameter of the adult macroconch phragmocone ranges from 85 mm to at least 130 mm (160 mm ?) so that this is one of the larger species of *Substeuerocheras* known from Mexico. The shell is planulate, moderately involute, with slightly compressed subquadrate whorl section (Text-fig. 25C). The umbilicus is fairly wide with steep umbilical wall; flanks and venter are flat or weakly convex, separated by a rounded shoulder.

The inner whorls are covered with sharp dense ribs, which are rursiradiate on the umbilical wall. On the umbilical shoulder, they bend sharply forward and continue prorsiradiate on the flanks, sometimes with slight flexure on the outermost whorl. Bifurcation takes place in a zone near mid-flank. The secondaries cross the venter straight without any loss of strength. Some of the larger fragments may be parts of the body chamber; they have stout distant ribs on flanks and venter.

The phragmocones of the probable microconch, found together with the macroconchs, are about half as large ($D = 45-65$ mm); adulthood is indicated by the approximation of septa and egression of the body chamber as indicated by remnants of the umbilical seam. Several specimens (especially the weathered phragmocone McM - J 1511/50) display septal sutures, containing a shallow E, a trifid L, and several U lobes diminishing in depth towards the umbilical seam; the E/L saddle is wide with moderately deep incision (Text-figs. 25 A, B).

Remarks. — *S. stantoni* Anderson from northwestern California, based upon ill-preserved and highly distorted small specimens, resembles our probable microconch but appears to have a narrower venter, as far as can be ascertained; *S. stantoni* is here regarded as a *nomen dubium*. *S. extans* Leanza (1945, p. 30, pl. VII, figs. 1-2) from Argentina carries similar stout ribs as the macroconch of *S. catorcense* but they arch slightly on the venter. *S. kocneni kellumi* Imlay (1939, p. 50, pl. 14, figs. 1-4) has denser, finer, and more flexuous ribs. Our probable microconch differs from *S. subquadratum*

Imlay (1939, p. 49, pl. 15, figs. 12-15) in the coarser ribbing. *S. alticostatum* Imlay (1939, p. 51, pl. 15, figs. 1-7) has higher whorls and coarser ribs.

Occurrence.—El Verde Member, La Caja Formation, Sierra Catorce.

Age.—Upper Tithonian.

Measurements (types and figured specimens only).—

	D	U	U/D	H	W	H/W	P/¼ wh.	S/¼ wh.
Holotype ♀	125.0	40.0	0.32	49.0	c.33.0	1.48	15	26
	93.0	c.32.0	0.34	38.0	c.31.0	1.22	14	—
Allotype, ? ♂	43.5	16.00	0.36	16.00	16.00	1.00	14	—
	40.00	14.00	0.35	15.00	13.5	1.11	14	—
Paratype 1, ♀	c.124.0	40.0	0.32	45.0	39.0	1.15	13	23
				40.0	c.34.0	1.17		
McM - J 1515C/1	84.0	30.0	0.35	32.5	26.0	1.25	14	24
	67.0	24.5	0.36	24.5	24.0	1.02	11	20

Substeuerocheras koeneni (Steuer), 1897

1897. *Odontoceras koeneni* Steuer, Palaeont. Abhand. Jena, N.D., Band 3, Heft 3, pl. XVII, figs. 1-3 [♀], 4-5 [? ♂], (Transl.: 1921, Act. Acad. Nac. Cienc. Córdoba, vol. 7, p. 73, same as pl. & figs.).
1897. *Odontoceras permulticostatum* Steuer, *ibid.*, pl. XXIII, figs. 1-2. (Transl.: *ibid.*, p. 84, same pl. & figs.).
1897. *Odontoceras fasciatum* Steuer, *ibid.*, pl. XVII, figs. 1-3, (Transl.: *ibid.*, same pl. & figs.).
- ?1897. *Odontoceras subfasciatum* Steuer, *ibid.*, pl. XIX, figs. 1-3. (Transl.: *ibid.*, p. 75, same pl. & figs.).
- ?1897. *Odontoceras intercostatum* Steuer, *ibid.*, pl. XXII, figs. 1-5. (Transl.: *ibid.*, p. 74, same pl. & figs.).
1912. *Steuerocheras lamellicostatum* Burckhardt, Inst. Geol. México, Bol. 29, p. 167, pl. XL, figs. 1-4, 6.
- ?1912. *Steuerocheras durangense* Burckhardt, *ibid.*, p. 169, pl. XL, figs. 5, 7-10.
1923. *Substeuerocheras koeneni* (Steuer), Spath, Geol. Soc. London, Quart. J., vol. 79, pt. 3, p. 305 [*gen. nov.*].
- ?1939. *Substeuerocheras kellumi* Imlay, Geol. Soc. America, Bull. 50, p. 50, pl. 14, figs. 1-4 [*subsp.*].
- ?1939. *Substeuerocheras* n. sp. aff. *S. subfasciatum* (Steuer), *ibid.*, p. 50, pl. 15, fig. 9.
1945. *Substeuerocheras koeneni* (Steuer), Leanza, Anal. Mus. de la Plata, no. 1, p. 28, pl. V, figs. 7, 8; pl. VII, fig. 4.

Substeuerocheras koeneni tabulatum Verma and Westermann, n. subsp.

[♀ + ? ♂]

Pl. 48, fig. 5; Pl. 49, figs. 1-2

Holotype.—McM - J 1510/2, a mature macroconch phragmo-

cone with one side and venter well exposed; other side crushed and filled with matrix.

Paratype/allotype. — McM - J 1517/2, phragmocone of possible microconch; one side well preserved; venter and other side partially damaged and crushed.

Locus typicus. — Locality 31, hill slope 2 km northwest of Cieniguita, Sierra Catorce. Paratype/allotype: locality 25, outcrop on steep hill slope immediately north of La Leona, Sierra Catorce.

Stratum typicum. — Upper part of El Verde Member, La Caja Formation.

Derivatio nominis. — After the tabulate venter.

Age. — Upper Tithonian.

Diagnosis. — A subspecies of *S. koeneni* (Steuer) with a tabulate venter and more distant, less flexuous ribs.

Material. — Nine phragmocones; mostly macroconchs: one from loc. 22 (McM - J 1508/76); two from loc. 31 (McM - J 1510/2, 25); one from loc. 32 (McM - J 1511/80); two from loc. 19A (McM - J 1515/6, 16); two from loc. 30 (McM - J 1516/1, 4) and one from loc. 25 (McM - J 1517/2). J 1510/2 (holotype) is well-preserved large macroconch phragmocone; J 1517/2 (paratype/allotype) is possibly a microconch. J 1515/16 is pathologic with early injury resulting in falcoid ribbing and low bifurcation on one flank, rectiradiate ribs bifurcating at almost mid-venter on the other. J 1510/25 is at UNAM.

Description. — The shell is planulate, somewhat evolute and of moderate size (D of phragmocone ≤ 90 mm). The umbilicus is moderately wide and deep with steep wall. The whorl section is compressed subelliptical with weakly convex flanks and tabulate venter. The inner whorls carry sharp dense, somewhat irregular ribs which are rursiradiate on the umbilical wall, curve gently to become prorsiradiate on or just above the shoulder, and are flexuous rectiradiate on the flanks. On the outer whorls, the ribs are more distant. Most ribs bifurcate at about $2/3$ whorl height; simple ribs are common and intercalatories rare. The secondaries cross straight over the venter. The single questionable microconch (D of phragmocone = 54 mm) is identical to the inner whorls of the macroconch and shows features indicating adulthood.

Remarks.—Our specimens are nearly identical with *Substeuerocheras koeneni* (Steuer) except that the venter is more markedly tabulate and the ribs on the outer whorls of the phragmocone are more distant and less flexuous. Of the two syntypes figured by Steuer (1897), the smaller one (pl. XVII, figs. 4-5) is almost identical with our questionable microconch and is probably the male dimorph. *S. koeneni kellumi* (Imlay, 1939, p. 49, pl. 14, figs. 1-4) is more narrowly coiled and bears denser and more flexuous ribbing. *S. catorcense*, n. sp. differs in the stouter ribs which are rather strongly flexed at the umbilical shoulder. *S. alticostatum* Imlay (1939, p. 51, pl. 15, figs. 1-7) is more evolute and has much coarser ribbing.

Occurrence.—El Verde Member, La Caja Formation, Sierra Catorce.

Age.—Upper Tithonian.

Measurements (types and figured specimens only).—

	D	U	U/D	H	W	H/W	P/¼ wh.	S/¼ wh.
Holotype ♀	90.0	28.0	0.31	36.0	c.29.0	1.24	14	24
	71.0	21.0	0.29	31.0	c.27.0	1.14	13	21
Paratype/ allotype (? ♂)	54.0	13.0	0.24	23.0	c.17.0	1.35	17	c.28
	41.0	10.0	0.24	19.0	15.0	1.26	15	27
McM - J 1515/16	46.0	15.5	0.33	20.0	19.0	1.05	16	—

Genus **ANDICERAS** Krantz, 1926

Type species: *A. trigonostomum* Krantz, 1926 (S. D. Arkell, *et al.*, 1957).

Andiceras lenki (Aguilera), 1895

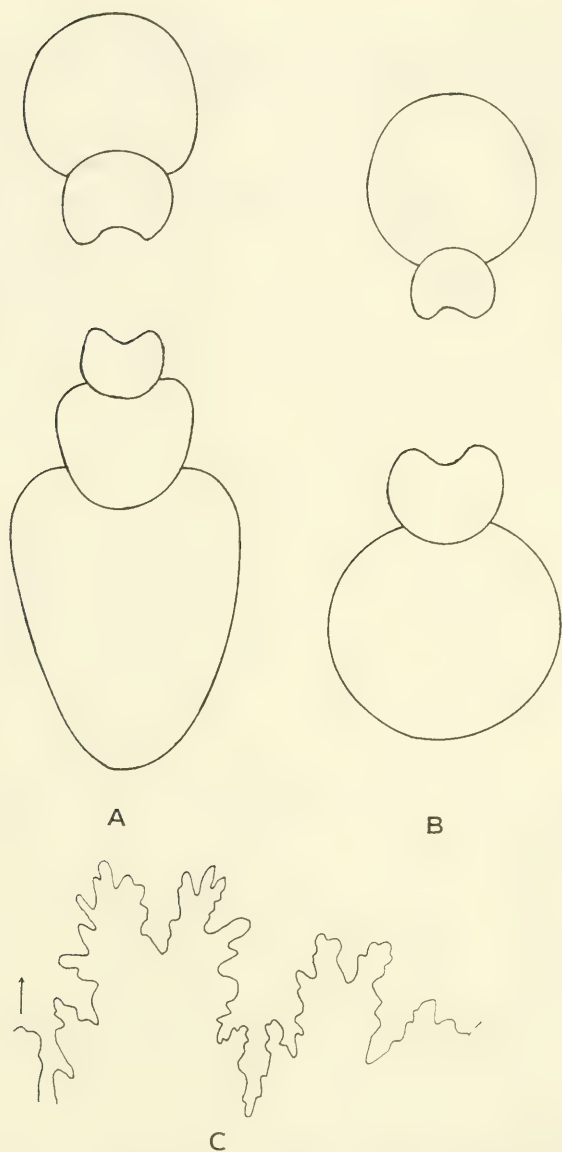
Pl. 43, fig. 2; Pl. 51, figs. 3-4; Pl. 52, fig. 1; Text-figs. 27A, 27C

1895. *Perisphinctes lenki* Aguilera in Castillo and Aguilera, Com. Geol. México, Bol. 1, p. 27, pl. VII, fig. 7.

?1895. *Perisphinctes dolfussi* Aguilera, *ibid.*, p. 33, pl. XXII, fig. 4 [*nom. dub.*]

1939. *Aulacosphinctes* sp. Imlay, 1939, Geol. Soc. America, Bull. 50, p. 42, pl. 15, figs. 10, 11.

Material.—This species is abundant in the Virgatosphinctinae beds, upper part of El Pastor Member of the La Caja Formation. Most of the specimens are either fragmentary or covered with unextractable matrix. The following better preserved specimens are chosen to exemplify this species: four from loc. 23A (McM - J



Text-fig. 27. — Cross sections through phragmocones and septal sutures of *Andiceras* spp. A. *Andiceras lenki* (Aguilera), McM - J 1506/5, $\times 1$. B. *A. monserati* (Aguilera) ♀, McM - J 1509/9, $\times 1$. C. *A. lenki* (Aguilera), McM - J 1506/7, at H = 15.5 mm.

1505/1, 2, 3, 125); fifteen from loc. 23B (McM - J 1506/1, 2, 4-7, 18, 127-133, 135); nine *ex situ* from Los Alamitos (McM - J 1509/3, 5, 6, 7, 219, 224, 240, 324, 326); and seven from loc. 40 (McM - J 1530/4, 17, 18, 52, 60, 63, 77).

Description. — The shell is planulate and moderately evolute with approximately 10-15% whorl overlap. The whorl section of the innermost whorls is subcircular, becoming somewhat depressed; the outer whorls are compressed ovate, somewhat higher than wide. The flanks are strongly convex in the inner whorls, decreasing in convexity with growth; in the outermost whorl, they converge and curve into the weakly convex venter (Text-fig. 27A). The ribs are sharp and prorsiradiate. Almost every rib bifurcates at or slightly above the middle of the flank; triplicate, simple ribs and intercalatories are rare. The secondaries are weakly projected and subcontinuous, barring a mid-ventral depression which is persistently present throughout growth. The ribs gradually become coarser and more distant on the outer whorls. The septal suture (Text-fig. 27C), traced after grinding away the ribs and, therefore, simplified, shows a deep E, a wide trifold L of similar depth, and a small somewhat oblique U₂.

Remarks. — Aguilera's holotype, by monotypy (UNAM 25), is a slightly distorted phragmocone, well exposed on the venter and one side but corroded on the other side. This species was placed by Burckhardt (1930, p. 80) in *Kossmatia*, presumably because of the slight mid-ventral arching, and Imlay (1939, table 8) followed this classification. However, the evolute coiling, coarse primaries, weak projection of the secondaries and, particularly, the slight mid-ventral depression with subcontinuous secondaries of *A. lenki* militate against *Kossmatia*. *Aulacosphinctes*, bearing a marked mid-ventral depression, is also ruled out because (contrary to Treatise, p. L356) it is said (Enay, *in litt.*) to have lateral tubercles at least in the early stages. Whorl shape, coiling and ornamentation indicate to us that this species is best classified under *Andiceras*, hitherto known from Argentina only.

The holotype by monotypy of "*Perisphinctes dolfussi*" Aguilera (UNAM 13) appeared to have continuous secondaries on the venter, but, upon preparation, was found to be a pathologic specimen. A

shell injury at an early age resulted in the displacement of the secondaries from the mid-ventral position to near the ventro-lateral shoulder where they are seen to be arched anteriorly (Pl. 51, fig. 3). "*P. dolfussi*" is, therefore, regarded as a *nomen dubium*. It is, furthermore, probable that the specimen is a pathologic *A. lenki*, so that both names become tentative synonyms.

A. lenki differs from *A. monserati* (Aguilera) (Castillo and Aguilera, 1895, p. 34, pl. XVII, fig. 2; pl. XXII, fig. 3) by the much finer ribs at all diameters. Two specimens of "*Aulacosphinctes* sp." described by Imlay (1939) from Coahuila, northern Mexico, were examined by Verma at the Museum of Paleontology, University of Michigan; they closely resemble *A. lenki* in whorl shape and ornamentation.

The type species of *Andiceras*, *A. trigonostomum* Krantz (1928, p. 37, pl. II, figs. 1a, b) from the Tithonian of Argentina, is more evolute, almost serpenticone. The type locality is "Arroyo Paraguay" (meaning Paraguay Creek) in the province of Mendoza, Argentina (not "Paraguay", Treatise, p. L352). *A. acuticostum* Krantz (*op. cit.* p. 38, pl. II, figs. 2a, b), also from the Tithonian of Mendoza, has a broader subelliptical whorl section and some simple ribs.

Occurrence. — El Pastor Member, La Caja Formation, Sierra Catorce.

Age. — Upper part of Lower Tithonian.

Measurements (types and figured specimens only). —

	D	U	U/D	H	W	H/W	P/¼ wh.	S/¼ wh.
Holotype	68.0	25.5	0.37	27.0	19.5	1.38	12	24
	c.48.0	c.17.0	0.35	20.0	c.17.5	1.14	11	20
" <i>P. dolfussi</i> "	61.5	21.5	0.35	24.0	c.19.0	1.26	11	24
	49.0	18.0	0.36	19.5	15.5	1.25	10	20
McM - J 1505/1	22.6	8.5	0.37	9.9	9.0	1.10	8	c.16
- J 1509/6	60.0	22.0	0.36	22.5	18.0	1.25	10	19

***Andiceras monserati* (Aguilera), 1895 [♀ + ? ♂]**

Pl. 52, figs. 2-3; Pl. 53, fig. 1; Text-fig. 27B

1895. *Perisphinctes monserati* Aguilera in Castillo and Aguilera, Com. Geol. México, Bol. 1, p. 34, pl. XXII, fig. 3 [lectotype, here designated], pl. XVII, fig. 2.

?1939. *Aulacosphinctoides* ? aff. *diversicostatus* (Burckhardt), Imlay, Geol. Soc. America, Bull. 50, p. 36, pl. 10, fig. 7.

Material. — Fifty to sixty specimens, mostly complete phragmocones of macroconchs, some probably with part of the crushed body chamber. The following specimens are relatively well preserved: two from loc. 23A (McM - J 1505/4, 5); ten from loc. 23B (McM - J 1506/3, 8-13, 16, 19, 136); four *ex situ* from Los Alamitos (McM - J 1509/3, 8, 9, 10); one *ex situ* from Cieniguita (McM - J 1514/1); one from loc. 40C (McM - J 1528/1); two from loc. 40E (McM - J 1529/1, 3) and one from loc. 40F (McM - J 1530/1). J 1506/3 is probably a microconch. Most specimens have matrix in the umbilicus, which is difficult to remove without damaging the fossil.

Description. — The shell is planulate and evolute, with approximately 10-15% whorl overlap. The diameter of the largest macroconch phragmocone is 132 mm. The whorl section is at first depressed ovate becoming subcircular with the intermediate whorls, while the outer whorls (> 60 mm D) are somewhat compressed subrectangular (Text-fig. 27B). Flanks and venter of the inner whorls are strongly convex becoming flattish and with slightly converging flanks in the later whorls. The umbilical slope is rounded throughout growth.

All whorls have coarse ribs which begin at the umbilical seam. On the outer whorls, they tend to be rursiradiate on the umbilical slope, curving forward on the umbilical shoulder, and proceeding prorsiradiate, sometimes weakly flexuous onto the flank. Most ribs bifurcate at approximately mid-flank into somewhat projected secondaries. These are usually subcontinuous at mid-venter, marked by a depression, and comprise a very obtuse angle or curvature which decreases with growth.

The probable micronconch is small (phragmocone D = 40 mm) and similar to the inner whorls of the macroconch; approximation of septa indicates adulthood.

Remarks. — This species is associated with *Andiceras lenki* (Aguilera) from which it differs in the larger diameter, the much coarser ribs, and the flattish venter of the outer whorls. Imlay's (1939, p. 36, pl. 10, fig. 7) "*Aulacosphinctoides* ? aff. *diversicostatus* (Burckhardt)" also resembles *A. monserati*. An examination of this specimen at the U.S. National Museum by Verma revealed, how-

ever, that the venter is poorly known due to the firm embedding in a concretion.

Of the two syntypes of "*P.*" *monserrati* figured by Aguilera, the lectotype (here designated: pl. XXII, fig. 3, refigured here, Pl. 53, fig. 1) although smaller, is undistorted and has better preserved inner whorls than the somewhat larger distorted paralectotype (pl. XVII, fig. 2).

Occurrence.—Upper part of El Pastor Member, La Caja Formation, Sierra Catorce.

Age.—Upper part of Lower Tithonian.

Measurements (types and figured specimens only).—

	D	U	U/D	H	W	H/W	P/whorl
Lectotype	58.0	24.0	0.41	21.0	19.3	1.08	30
Paralectotype	77.4	c.34.0	0.43	24.4	27.8	0.87	24
MeM - J 1506/3 (? ♂)	42.0	20.0	0.47	13.0	15.0	0.86	27
- J 1509/9 (♀)	97.0	38.0	0.39	32.5	30.0	1.08	37

Subfamily HIMALAYITINAE Spath, 1923

Genus CORONGOCERAS Spath, 1925

Type species: *C. lotenoense* Spath, 1925 [= "*Hoplites kolic-keri*" Haupt, 1907, *non* Oppel, 1863].

The only species originally placed in *Corongoceras* was the type species from Corongo, Peru. Other species from South America subsequently transferred to or described under this genus are:

Hoplites mendozanus Behrendsen, 1892

Berriasella alternans Gerth, 1925

C. duraznense Krantz, 1928 [= ? *C. mendozanum*]

C. submendozanum Krantz, 1928

C. rigali Leanza, 1945

Imlay (1942) added *C. filicostatum* from Cuba. Our collections from Sierra Catorce contain two or three distinct species, one previously known from Argentina, the other one or two new.

Corongoceras mendozanum (Behrendsen), 1892 Pl. 54, fig. 2; Text-fig. 28A

1892. *Hoplites mendozanus* Behrendsen, Deutsch. Geol. Ges., vol. 2, pl. II, figs. 4a-c (Transl.: Act. Acad. Nac. Cienc. Córdoba, t. VII, p. 181, same pl. & figs.).

1928. *Corongoceras mendozanum* (Behrendsen), Krantz, Act. Acad. Nac. Cienc. Rep. Argentina, vol. X, p. 29, pl. IV, figs. 3, 4.

Material. — One well-preserved mold of phragmocone, innermost whorls missing, from loc. 14A (McM - J 1526/25); one crushed small fragment from loc. 24 (McM - J 1509/329).

Description. — The shell is planulate and highly evolute, almost serpenticone. The whorl section of the earlier whorls is subquadrate, becoming subcircular on the outermost whorl (Text-fig. 28A). The umbilicus is wide and shallow, with rounded wall. The ribs are sharp and evenly spaced on the inner and outer whorls. The primaries arise at the umbilical seam almost rectiradiate; there are about 33 on the outer whorl and about 25 in the penultimate whorl. On the inner whorls, every second, more rarely every third, primary carries a lateral tubercle adjacent to the subsequent umbilical seam. On the outer whorls, these tubercles placed at about $3/4$ whorl height, become more prominent and triangular. The secondaries are slightly projected; there are about 48 on the outer whorl. Ventral tubercles, somewhat thinner than the lateral tubercles, occur in opposition besides the depressed mid-ventral region which is crossed by somewhat reduced ribs.

Remarks. — *C. mendozanum* differs from *C. submendozanum* Krantz by the coarser ribs of the inner whorls. *C. alternans* (Gerth) has much more prominent and irregularly spaced ribs throughout and is more involute and inflated. *C. duraznense* Krantz closely resembles *C. mendozanum* and may be conspecific.

Occurrence. — El Verde Member, La Caja Formation, Sierra Catorce.

Age. — Upper Tithonian.

Measurements (figured specimen only). —

	D	U	U/D	H	W	H/W
McM - J 1526/25	60.00	30.00	0.50	18.5	18.0	1.02

Corongoceras cordebai Verma and Westermann, n. sp. [♀ + ?♂]
Pl. 52, figs. 4-5; Pl. 53, figs. 2-5; Pl. 54, fig. 1; Text-fig. 28B

Holotype. — McM - J 1517/42, an almost complete somewhat

distorted probable macroconch (♀), internal mold with crushed body chamber and damaged venter.

Allotype. — McM - J 1494/102, phragmocone of probable microconch (♂) with remains of adult body chamber.

Paratype. — McM - J 1517/38, probable macroconch, well-preserved, undistorted fragment of phragmocone from loc. 25 (La Leona).

Locus Typicus. — Holotype and allotype from loc. 25, outcrop on hill slope just north of La Leona, Sierra Catorce.

Stratum typicum. — Lower part of El Verde Member, La Caja Formation.

Derivatio nominis. — After Ingeniero Diego A. Córdoba, Director of Instituto de Geología, Universidad Nacional Autónoma de México.

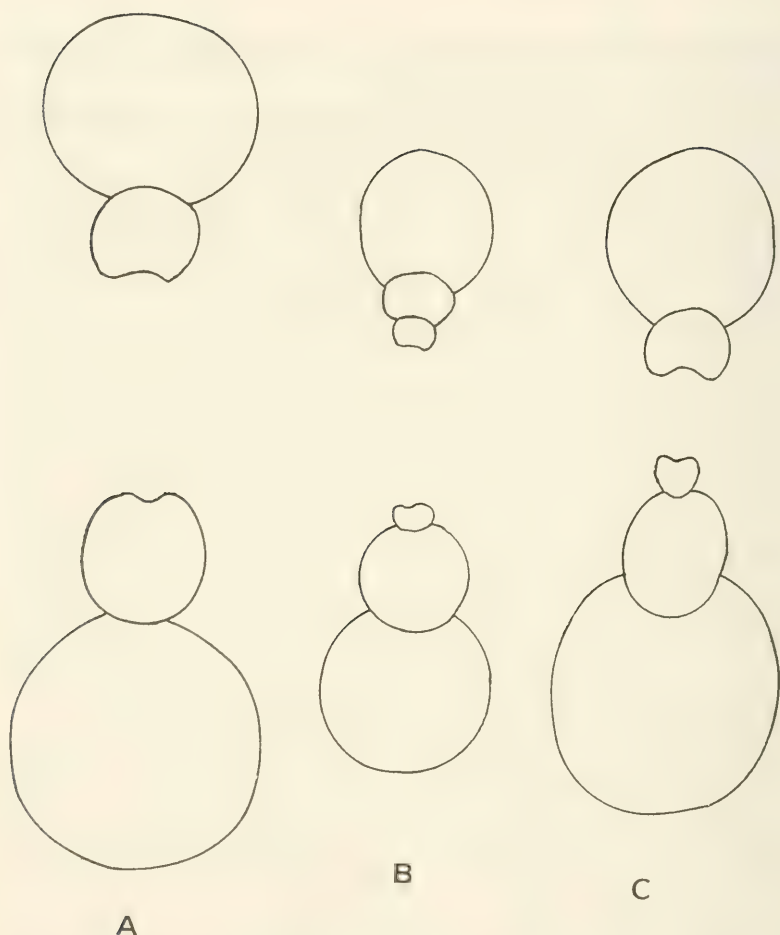
Diagnosis. — A small, slightly involute species of *Corongoceras* with simple bituberculate ribs only.

Material. — The type specimens and two crushed fragments from loc. 1A (McM - J 1494/59, 112); one macroconch fragment from loc. 2 (McM - J 1495/70); five macroconch fragments from locs. 25 (McM - J 1517/36, 78), 14A (McM - J 1526/80) and 15 (McM J 1535/22, 23) respectively. J 1535/22 is at UNAM.

Description. — The shell is of moderate size, the apparent macroconch phragmocone diameter varying about 70 mm and the apparent microconch diameter about 40 mm. The shell is evolute, almost serpenticone and planulate with wide and shallow umbilicus. The cross section of the outer whorls is subcircular with gently rounded umbilical shoulder (Text-fig. 28B).

The ornament of the outer whorl consists of rectiradiate, simple prominent widely and evenly spaced bituberculate ribs, which originate at the umbilical seam and traverse the flanks. There are 41 ribs in the outermost whorl of the holotype and 32 on the penultimate whorl. The lateral tubercles are consistently located at approximately $3/4$ whorl height, at the line of involution. The ventro-lateral tubercles which may be remnants of spines, occur in regular opposition beside the mid-ventral rib depression and are somewhat thicker than the lateral tubercles. The septal suture is not preserved.

Remarks. — This is the only known species of *Corongoceras* with regular simple (unbranched) bituberculate ribs.



Text-fig. 28. — Cross sections through phragmocones of *Corongoceras*, $\times 1$. A. *C. mendozanum* (Behrendsen), McM - J 1526/25. B. *C. cordabai*, n. sp., McM - J 1517/36. C. *Corongoceras* ?, n. sp. indet., McM - J 1511/5.

Occurrence. — Lower part of El Verde Member, La Caja Formation, Sierra Catorce.

Age. — Upper Tithonian.

Measurements. —

	D	U	U/D	H	W	H/W	P
Holotype ♀	70.0	40.0	0.57	c.17.0	c.23.0	0.73	41/ wh.
Paratype ♀	75.0	40.0	0.53	21.0	20.0	1.05	23/½ wh.
Allotype ? ♂	40.0	20.0	0.50	11.0	10.5	1.04	18/½ wh.
McM - J 1495/70 ♀	—	—	—	17.5	17.5	1.00	11/¼ wh.
- J 1535/23 ♀	—	—	—	18.5	18.8	0.98	13/¼ wh.
McM - J 1526/80 ♀	—	—	—	24.0	23.5	1.02	9/¼ wh.

Corongoceras ? n. sp. indet.

Pl. 54, figs. 3-4; Text-fig. 28C

Material. — Four moderately preserved incomplete specimens: one from loc. 21 (McM - J 1504/1); one from loc. 22 (McM - J J 1508/73); and two from loc. 32 (McM - J 1511/5, 77).

Description. — The shell is small ($D = 42$ mm), only moderately evolute and planulate, with subcircular to subovate whorl section and about 20% overlap. The moderately convex flanks merge gradually with the narrowly flattened venter (Text-fig. 28C). The umbilicus is moderately wide ($U = 0.30-0.40 D$) with curved umbilical slope. The coarse, somewhat distantly spaced ribs originate rursiradiate at the umbilical seam, curve forward on the umbilical shoulder and become prorsiradiate on the flank. Most of the ribs, especially on the earlier whorls, remain simple. On the outermost whorl of McM - J 1511/5, only 7 out of 33 primaries bifurcate. A slight swelling may be present at the point of bifurcation. There are thick clavate tubercles at the ventro-lateral margin which border on a smooth mid-ventral band. The septal suture is not available for study.

Remarks. — The classification of these specimens under *Corongoceras* is questioned because marked lateral tubercles are absent; only faint swellings are observed. In thickness of ribbing our specimens resemble the Argentine "*Hoplites*" *vetustus* Steuer (1897, pl. XVI, figs. 4-10; transl.: 1921, p. 85, same pl. & figs.) which Leanza (1945, p. 45, pl. V, figs. 9-11) transferred to *Micracanthoceras*. Steuer originally compared this species with *Blanfordiceras wallichii* Gray, the type species of *Blanfordiceras* Cossmann. Enay (*in litt.*) agrees with the classification under *Blanfordiceras*, not *Micracanthoceras*. The moderate to strong projection of the secondary ribs and the absence of lateral tubercles in both Steuer's and Leanza's material of "*H.*" *vetustus* appear to confirm Enay's opinion.

Occurrence. — El Verde Member, La Caja Formation, Sierra Catorce.

Age. — Upper Tithonian.

Measurements (figured specimens only). —

	D	U	U/D	H	W	H/W	P/wh.
McM - J 1504/1	29.5	8.3	0.28	12.5	11.5	1.08	36
- J 1511/5	42.0	16.0	0.38	14.5	14.5	1.0	c.33

Genus **MICRACANTHOCERAS** Spath, 1925

Type species: *Ammonites microcanthus* (Oppel, 1865) Zittel, 1868.

Micracanthoceras is classified here as a genus, not a subgenus of *Himalayites* Uhlig as in the Treatise (Arkell, *et al.*, 1957, p. L356). According to its apparent affinity to *Durangites*, *Micracanthoceras* could perhaps be placed as a subgenus in *Durangites* Burckhardt. *Micracanthoceras* is rare in Sierra Catorce; only two specimens representing one or possibly two species are present in our collection. It is, however, an important element in the Tithonian of southeastern Europe. According to Enay (*in litt.*) the diagnostic attributes of *Micracanthoceras* are the alternation of simple with plicate or triplicate ribs and tubercles at the point of branching.

Micracanthoceras acanthellum Imlay, 1939

Pl. 55, fig. 1

1939. *Micracanthoceras acanthellum* Imlay, Geol. Soc. America, Bull., vol. 50, p. 43, pl. 16, figs. 8-11.

Material. — A probably adult complete phragmocone with impressed remains of body chamber from loc. 22 (McM - J 1508/98); ? one incomplete phragmocone from loc. 18 (McM - J 1503/20).

Description. — The shell is planulate evolute with subcircular cross section of early whorls becoming ovate to subrectangular in later stages. The outer whorls have weakly convex flanks and a nearly flat venter. The umbilicus is wide and moderately deep with steep, nearly vertical wall. The early whorls carry dense sharp flexuous ribs of which many are simple. Every second or third rib is biplicate with prominent pointed lateral tubercles at the point of branching located at the umbilical seam of the subsequent whorl. The outer whorls have radially elongate irregular ventro-lateral tubercles and subcontinuous ribs. The ribs are rursiradiate at the umbilical seam, curve forward at the umbilical shoulder, and are prorsiradiate over most of the flank. On the last half whorl of the

phragmocone and on the body chamber, the lateral tubercles are reduced to faint swellings but the ventral tubercles persist and continue to grow thicker with growth. The ornament on the incomplete larger specimen (McM - J 1503/20) is markedly coarser than on the more complete smaller specimen (McM - J 1508/98).

Remarks. — Of the two specimens, the smaller more complete phragmocone is nearly identical to *M. acanthellum* Imlay from San Pedro del Gallo, Durango. The other specimen (McM - J 1503/20), on account of its coarser ornament, may be either a variant or a closely related species. *M. alamense* Imlay (1939, p. 45, pl. 9, figs. 3-12) from Coahuila, northern Mexico, is smaller and has much weaker lateral and ventral tubercles and fewer simple ribs. *M. aguajitense* Imlay (1939, p. 43, pl. 14, figs. 5-7), based on rather imperfectly preserved material, is more evolute and has irregularly placed ventral tubercles.

Occurrence. — El Verde Member, La Caja Formation, Sierra Catorce.

Age. — Upper Tithonian.

Measurements (type and figured specimen only). —

	D	U	U/D	H	W	H/W	P/wh.
Holotype (UM 19580)	46.0	18.5	0.40	16.5	16.5	1.00	c.40
McM - J 1508/98	52.0	18.5	0.35	c.22.0	18.0	1.22	44

Genus **DURANGITES** Burckhardt, 1912

Type species: *D. acanthicus* Burckhardt, 1912 (SD. Roman, 1938).

Discussion. — The discovery of *Durangites* in the Tithonian part of the Akkuyu Formation of Turkey (Enay, *et al.*, 1971) renewed the interest in this genus which was hitherto considered indigenous to Mexico and Cuba (Burckhardt 1912, Imlay 1939, 1942).

In proposing the genus, Burckhardt (1912, p. 144) wrote [our translation] "*Durangites* comprises rather small forms, with flattened shell and more or less open umbilicus. The external part is more or less flat. The umbilical wall is abrupt. The whorl section is rounded [sub] quadratic or more or less rectangular. The shell growth is rather slow".

Burckhardt (*loc. cit.*) distinguished four growth stages [French "stades"] on types of ornamentation:

(i) "*Microcanthus* stage", characterized by straight and fine ribs, sometimes simple, sometimes forked; lateral tubercles feeble; ventral tubercles small; smooth mid-ventral band.

(ii) "*Kollikeri* stage", characterized by straight ribs, some forked, others simple, inequal ventro-lateral tubercles; feeble lateral tubercles.

(iii) "*Typical* stage", characterized by a tendency of ribs to be orad convex at mid-flank [probably indicating early development of lappets in micronconchs]; disappearance of lateral tubercles; ventral tubercles well developed and prominent, placed at irregular intervals, elongated radially [bullate]; ribs generally divided on flank, with simple ribs and intercalatories present; sometimes two ribs meet at the venter to form a tubercle.

(iv) "*Adult* stage", characterized by disappearance of the ventro-lateral tubercles and replacement of smooth ventral band with subcontinuous weakened ribs, which may curve adorally.

According to Burckhardt (*loc. cit.*), the various species of *Durangites* differ in the occurrence of those "stages" at different times during morphogeny. Burckhardt (1912) did not name a type species. Out of the several species described (*op. cit.*), Roman (1938) subsequently designated *D. acanthicus*. This was an unfortunate choice, because this dubious species was based upon a single, somewhat damaged incomplete specimen (probably microconch), of modest preservation. Furthermore, according to Burckhardt, *D. acanthicus* has only two of the four ornament "stages" fully developed, with the "typical stage" commencing only towards the very end. More typical of *Durangites* is *D. vulgaris*, represented by several well-preserved specimens, which has three of the four "stages" fully developed. Furthermore, it appears that the specimens of *D. vulgaris*, figured by Burckhardt, include both macroconchs and microconchs (see below). The presence of lappets in *D. astillerensis* Imlay (1939, p. 46, pl. 10, figs. 10-12) from Sierra de Parras, Coahuila, suggests the possibility that future research may yield microconchs also among the various other *Durangites* "species" of Burckhardt.

On the basis of Burckhardt's (1912) and Imlay's (1939) descriptions and the generally accepted criteria for dimorphism (*i.e.* association, identity of inner whorls, apertural modifications, septal approximation) the following tentative suggestions are made here regarding the dimorphism and synonyms of Mexican *Durangites* species. Where two microconchs are shown opposite a macroconch, either or both may be paired with the indicated macroconch:

Probable Macroconchs (♀)	Probable Microconchs (♂)
<i>Durangites</i> cf. <i>D. acanthicus</i> (Imlay, 1939, p. 147, pl. 17, figs. 6, 7)	<i>D. acanthicus</i> Burckhardt (1912, p. 146, pl. XXXVI, figs. 7, 8, 10, 11, 15) [Syn.: <i>D. incertus</i> Burckhardt (1912, p. 147, pl. XXXVI, figs. 12-14, 16, 17)]
<i>D. vulgaris</i> Burckhardt (1912, pl. XXXVIII, figs. 1-4; pl. XXXVII, figs. 1, 2, 5, 18)	<i>D. vulgaris</i> Burckhardt (1912, pl. XXXVII, figs. 3, 4, 6-9, 13, 25, 27 + ? others on same plate)
<i>D. densestriatus</i> Burckhardt (1912, p. 152, pl. XXXVI, figs. 22-24, 26, 27)	<i>D. vulgaris</i> Burckhardt (1912, pl. XXXVII, figs. 16, 17, 19-21 + ? others on same plate)
<i>D. humboldti</i> Burckhardt (1912, p. 152, pl. XXXVI, figs. 18-21, 25)	<i>D. latesellatus</i> Burckhardt (1912, p. 156, pl. XXXVIII, figs. 11, 12, 15, 17)
	<i>Durangites</i> sp. ind. (Burckhardt, 1912, pl. XXXVII, figs. 18-20, 22)
<i>D. rarifurcatus</i> Imlay (1939, p. 48, pl. 17, fig. 8)	<i>D. aff. rarifurcatus</i> (Imlay, 1939, p. 48 pl. 17, fig. 9)

D. n. sp. ind. (Imlay, 1939, p. 48, pl. 17, fig. 9)

D. astillerensis (Imlay, 1939, p. 48, pl. 10, figs. 10-12)

D. n. sp. ind. (Imlay, 1939, p. 48, pl. 17, figs. 10-11)

?

D. fusicostatus Burckhardt (1912, p. 159, pl. XXXVIII, figs. 8, 13, 14, 16)

D. nodulatus Burckhardt (1912, p. 155, pl. XXXVIII, figs. 5-7, 9, 10)

?

***Durangites acanthicus* Burckhardt, 1912 [? ♂]**

Pl. 55. fig. 7

1912. *Durangites acanthicus* Burckhardt, Inst. Geol. México, Bol. 29, p. 146, pl. XXXVI, figs. 7, 8, 10, 11, 15 [? ♂].

?1912. *Durangites incertus* Burckhardt, *ibid.*, p. 147, pl. XXXVI, figs. 12-14, 16, 17 [? ♂].

1939. *Durangites* cf. *D. acanthicus* Burckhardt, Imlay, Geol. Soc. America, Bull. 50, p. 47, pl. 17, figs. 6, 7 [? ♂].

Material.—One phragmocone, probably a microconch with beginning of crushed body chamber, from loc. 25 (McM - J 1517/87).

Description.—The specimen is nearly identical to the holotype (monotypy). The shell is planulate, evolute, and has a slightly subovate tabulate whorl section with strongly convex flanks. The shell is covered with sharp high ribs, which proceed from the umbilical seam almost rectiradiate. Some ribs remain simple; others, especially towards the anterior end of the shell, bifurcate at about mid-flank. Sporadic prominent tubercles occur at the ventro-lateral margin; 13 tubercles and about 45 secondaries are present on the outermost whorl.

Remarks.—*D. incertus* Burckhardt (1912), although somewhat more inflated, appears to be synonymous with *D. acanthicus*. Both are probably microconchs, while the "*D. cf. D. acanthicus*" of Imlay (1939) is probably the corresponding macroconch. The "*D. cf. D. acanthicus*" described by Peña (1964, p. 24, pl. 9, figs. 3, 5) has much coarser ribs than *D. acanthicus*.

Occurrence.—El Verde Member, La Caja Formation, Sierra Catorce.

Age. — Upper Tithonian.

Measurements. —

	D	U	U/D	H	W	H/W	S/wh.
Holotype	24.2	9.0	0.37	10.5	9.5	1.10	c.45
McM - J 1517/87	24.0	9.5	0.39	c.10.0	c.8.0	1.25	c.45

Durangites vulgaris Burckhardt, 1912, ♀
Pl. 55, figs. 5-6; Text-figs. 29A, 29B

1912. *Durangites vulgaris* Burckhardt, Inst. Geol. México, Bol. 29, p. 149, pl. XXXVII, figs. 1-35, pl. XXXVIII, figs. 1-4 [♀ + ♂].

?1912. *Durangites densestriatus* Burckhardt, *ibid.*, p. 152, pl. XXXVI, figs. 22-24, 26, 27 [? ♀].

1942. *Durangites vulgaris* Burckhardt, Imlay, Geol. Soc. America, Bull. 53, p. 1453, pl. 3, fig. 1 [? ♀].

Material. — Six specimens, mostly internal molds of phragmocones: two from loc. 22 (McM - J 1508/5, 58); two from loc. 32 (McM - J 1511/4, 76); one from loc. 16 (McM - J 1536/3); and one from loc. 20A (McM - J 1538/1).

Description. — The specimens are nearly identical to the larger phragmocones figured by Burckhardt (1912) under *D. vulgaris*. The shell is planulate, evolute with subquadrate whorl section, slightly higher than wide. The flanks are weakly convex, the venter is almost flat and the umbilicus fairly wide with steep rounded umbilical slope (Text-fig. 29A). The ornament consists of sharp ribs and sporadic ventral tubercles. On the inner whorls, the primaries are denser than on the outer whorls. They are rursiradiate on the umbilical slope, gradually curve forward at the shoulder and are rectiradiate on the flanks. Some of the ribs on the outer whorls are weakly flexuous. The majority of the ribs on the outermost whorl bifurcate in the middle or upper third of the flank with the posterior branch of some secondaries curving backwards. Simple ribs and intercalatories are rare. On the outermost whorl, every third, fourth, or rarely fifth rib carries a pronounced tubercle at the ventrolateral margin.

This type of ornamentation characterizes the "typical stage" of *Durangites* of Burckhardt (1912, p. 144-145). On the two larger specimens (McM - J 1538/1 and J 1508/8), the tubercles appear to die out on the outermost quarter whorls, while the ribs become



Text-fig. 29. — Cross sections through phragmocones and septal sutures of *Durangites*. A. *D. vulgaris* (Burckhardt) ♀, McM - J 1511/4, $\times 1.3$. B. *D. vulgaris* ♀, McM - J 1508/58, at H = 13 mm, enlarged. C. *D. alencasteri* n. sp. ♀, McM - J 1508/6, at H = 17 mm, enlarged. D. *D. heilprini* (Aguilera), McM - J 1536/2, $\times 2$.

thin in the mid-ventral region; this indicates the beginning of the "adult stage" of Burckhardt (1912). The septal suture (Text-fig. 29B) has a small E, a deeper and trifid L, and two U lobes of diminishing depth.

Remarks. — *D. densestriatus* Burckhardt (1912) resembles some of the more densely ribbed syntypes of *D. vulgaris* and is, therefore, considered conspecific. The lectotype of *D. vulgaris* can be designated only after a study of the type material. *D. humboldti* Burckhardt (1912, p. 152, pl. XXXVI, figs. 18-21), although similar in whorl shape and coiling, has more distant ribs on the outermost whorl. The ribs of *D. crassicostatus*, n. sp. are much more distant and prominent. *D. cohglani* (Aguilera) differs by the finer ornament becoming irregular and finally obsolete on the outer phragmocone whorl.

Occurrence. — El Verde Member, La Caja Formation, Sierra Catorce.

Age. — Upper Tithonian.

Measurements (figured specimens only). —

	D	U	U/D	H	W	H/W	P/w.h.
McM - J 1508/58	38.5	11.0	0.20	16.5	13.5	1.22	—
- J 1511/4	36.0	13.0	0.36	14.5	13.7	1.05	42
- J 1538/1	55.5	15.5	0.28	25.0	c.17.0	1.47	c.48

Durangites heilprini (Aguilera), 1895 Pl. 43, fig. 4; Pl. 54, fig. 5;
Pl. 55, fig. 3; Pl. 56, fig. 5; Text-fig. 29D

1895. *Hoplites heilprini* Aguilera in Castillo and Aguilera, Com. Geol. México, Bol. 1, p. 41, pl. XXII, fig. 7.

Material. — Seventeen (+ ? four) phragmocones in various states of preservation; some are damaged, others covered with matrix on one side: four (+ ? one) from loc. 22 (McM - J 1508/30, 64, ?93, 112, 116); ? one from loc. 31 (McM - J 1510/24); five (+ ? two) from loc. 32 (McM - J 1511/2, ?70, 72, 83, 85, ?91, 342); one from loc. 19A (McM - J 1515/4); one from loc. 19D (McM - J 1515C/3); two from loc. 25 (McM - J 1517/80, 81); and four from loc. 16 (McM - J 1536/2, 8, 18, 25).

Description. — The shell is planulate and only moderately involute. The whorl section is subquadratic in the earlier whorls becoming compressed subrectangular in the outer ones (Text-fig. 29D). The umbilicus is relatively narrow with steep to vertical wall. The ornament consists of sharp, evenly spaced ribs which are usually simple on the inner whorls but more commonly biplicate on the outer whorls. Throughout the phragmocone, the ribs originate at or just above the umbilical seam, are directed backward on the umbilical wall, curve sharply forward on the umbilical shoulder, and traverse the flanks prorsiradiate with very weak flexure. Every rib has a bullate tubercle at the ventro-lateral margin. In the mid-ventral area, the ribs are subcontinuous with a marked reduction in height, sometimes locally creating a smooth band. The septal suture is not available for study. The four specimens questionably included in the material are larger, and have much coarser ornament on the outer whorl.

Remarks. — "*Hoplites*" *heilprini* and "*H.*" *cohglani*, Aguilera spp., appear to be the earliest described *Durangites*; yet they were not included by Burckhardt (1912) in his list comprising *Durangites*

species, presumably because the original illustrations were extremely poor. The holotype (by monotypy, UNAM 4) of *D. heilprini* is re-figured here (Pl. 43, fig. 4). This species is more involute and has finer, denser ribbing than *D. vulgaris* Burckhardt. It is distinguished from all other Mexican *Durangites* by the dense prorsiradiate ribbing, regular ventro-lateral tubercles, and the abundance of simple ribs. The four large specimens with coarser ornament on the outer whorl may be more complete (or ? macroconchs) and tentatively included in this species.

Occurrence. — El Verde Member, La Caja Formation, Sierra Catorce.

Age. — Upper Tithonian.

Measurements (figured specimens only). —

	D	U	U/D	H	W	H/W	P/¼ wh.	S/¼ wh.
Holotype	38.0	11.0	0.29	18.0	13.0	1.38		
McM - J 1508/93	c.86.0	30.0	0.34	34.0	27.0	1.25	c.13	18
	c.69.0	25.0	0.36	28.0	23.0	1.21	c.13	—
- J 1511/2	24.0	9.0	0.37	9.5	8.0	1.18	11	15
- J 1536/2	29.0	8.5	0.29	13.0	11.0	1.18	11	16
- J 1536/8	49.0	14.0	0.28	c.21.0	c.15.0	1.40	12	20
	40.0	12.0	0.30	c.17.0	c.12.0	1.41	12	18

Durangites aff. *D. heilprini* (Aguilera), 1895

Pl. 55, fig. 4

Material. — Three immature phragmocones: one from loc. 19A (McM - J 1515/8), one from loc. 25 (McM - J 1517/89), and one from loc. 16 (McM - J 1536/1).

Discussion. — The three specimens are similar to immature *D. heilprini* in whorl shape, coiling and type of ornament but differ in the even finer and denser ribbing (c. 55 *vs.* 40-45 per whorl at 25-30 mm D). Most of the ribs are simple, the others biplicate. Every rib has a tubercle at the ventro-lateral margin. This is probably a new species but more complete material is needed.

Occurrence. — El Verde Member, La Caja Formation, Sierra Catorce.

Age. — Upper Tithonian.

Measurements (figured specimen only). —

	D	U	U/D	H	W	H/W	P/wh.
McM - J 1515/8	28.0	8.0	0.29	12.0	10.5	1.14	55

Durangites cohglani (Aguilera), 1895

Pl. 43, fig. 3

1895. *Hoplites cohglani* Aguilera in Castillo and Aguilera, Com. Geol. México, Bol. 1, p. 40, pl. XXII, fig. 1 ([lectotype, here designated], pl. XXI, fig. 1).

Material. — The two syntypes; one (lectotype) is a well-preserved phragmocone (UNAM 3) from Rancho Alamitos; the other is a large phragmocone fragment with partly preserved inner whorls (UNAM 2).

Description. — The shell is medium large (phragmocone $D = 49$ to 65 mm), planulate and evolute, with subrectangular whorl section. The flanks are weakly convex and the venter nearly flat. The umbilicus is wide, moderately deep, with steep umbilical wall and broadly rounded shoulder. The inner whorls are covered with dense fine flexuous ribs which are rursiradiate at the umbilical wall but are curved at the shoulder to become prorsiradiate over the flanks. Some ribs, particularly on the inner whorls, bifurcate at irregular heights from the umbilical shoulder. On the outermost whorl of the phragmocone, the ribs maintain the same course but a marked change occurs in the prominence of the ribs; some ribs grow more prominent while the others become obsolete and striae-like. Simple ribs and intercalatories are quite common. The ventro-lateral shoulders carry sporadic but prominent tubercles of varying strength which die out towards the end of the phragmocone.

Remarks. — Aguilera figured two specimens (syntypes) of this species. Of these, the complete phragmocone (pl. XXII, fig. 1) is designated as the lectotype and refigured here (Pl. 43, fig. 3). The paralectotype is a fragment of a somewhat larger phragmocone with obsolete ornament on the outer whorl. In whorl shape and coiling, *D. cohglani* is similar to some of the larger syntypes of *D. vulgaris* Burckhardt (♀), but differs by the obsolescent ribbing of the adult phragmocone.

Occurrence. — Aguilera (in Castillo and Aguilera, 1895) recorded this species from his "Los Alamitos Beds". It may have come

from an exposure of the El Verde Member, La Caja Formation, in the vicinity of Los Alamitos (loc. 22 of this work).

Age. — Upper Tithonian.

Measurements. —

	D	U	U/D	H	W	H/W	P/wh.
Lectotype	49.0	17.0	0.34	20.0	16.5	1.21	c.40
Paralectotype	c.65	—	—	27.0	21.0	1.28	—

Durangites n. sp. aff. **D. rarifurcatus** Imlay, 1939

Pl. 55, figs. 8-9; Pl. 56, fig. 1

Material. — Eight specimens, mostly fragments of outer whorls: four from loc. 22 (McM - J 1508/4, 9, 33, 54); one from loc. 32 (McM - J 1511/60); and three from loc. 25 (McM - J 1517/39, 82, 83). J 1511/60 is probably a microconch.

Description. — The shell is planulate, with subquadrate to circular cross section of the earlier whorls becoming somewhat compressed in the later whorls. The flanks are weakly convex and round into the flat venter. The umbilicus is fairly wide with rounded umbilical slope. The inner whorls have coarse rectiradiate to prorsiradiate primaries of which every second or third has a small tubercle adjacent to the subsequent umbilical seam, and is somewhat flared. On the outer whorls, the ribs are more distant and rectiradiate; some are simple but the majority are branched. The points of bifurcation are usually either weakly swollen or have tubercles of varying prominence; but lateral tubercles are lacking on the largest septate fragments. Some of the secondaries, commonly the posterior one of a pair, carry a prominent ventro-lateral tubercle. Most simple ribs are nontuberculate. The simple ribs and secondaries cross the venter subcontinuously with a marked reduction.

Remarks. — In prominence of ribs, our specimens resemble *D. rarifurcatus* Imlay (1939, p. 48, pl. 17, fig. 8), known only in the damaged holotype. The small "*D. aff. rarifurcatus*" of Imlay (*loc. cit.*, fig. 9) is probably the corresponding microconch. However, the prominent sporadic lateral tubercles of the intermediate

whorls of our specimens appear to be absent in *D. rarifurcatus*. The larger of the two specimens described under *Durangites*, n. sp. ind. by Imlay (*loc. cit.*, fig. 12 only) is probably also a *D. rarifurcatus*. The identification of "*Durangites* cf. *D. acanthicus* Burckhardt" by Peña (1964) was based on a whorl fragment with like ribbing only. Our specimens may belong to a new species, but the material is insufficient for the naming of a new species.

Occurrence. — El Verde Member, La Caja Formation, Sierra Catorce.

Age. — Upper Tithonian.

Measurements (figured specimens only). —

	D	U	U/D	H	W	H/W	P/¼ wh.
McM - J 1508/4	—	—	—	25.0	c.19.0	1.31	11
- J 1511/60	45.0	17.0	0.37	17.5	15.0	1.16	14
- J 1517/82	—	—	—	17.0	17.0	1.00	—

Durangites alencasteri Verma and Westermann, n. sp. [♀ + ? ♂]
Pl. 55, fig. 2; Pl. 56, figs. 2-4; Text-fig. 29C

Holotype. — McM - J 1508/6, complete adult phragmocone of macroconch, one side well preserved, partly covered with matrix and crushed on the other.

Allotype. — McM - J 1508/7, phragmocone of (?) microconch, well exposed on one side and venter.

Paratype. — McM - J 1511/11 complete phragmocone of macroconch, both sides exposed, from Cieniguita (loc. 32).

Locus typicus. — Holotype and allotype from locality 32, outcrop on hill slope just northeast of Los Alamitos, Sierra Catorce.

Stratum typicum. — Lower part of El Verde Member, La Caja Formation.

Derivatio nominis. — After Dra. Gloria Alencáster, Paleontologist and Curator, Instituto de Geología, Universidad Nacional Autónoma de México.

Age. — Upper Tithonian.

Diagnosis. — A large species of *Durangites*, with inflated subquadratic whorl section; inner whorls with rectiradiate moderately dense ribs; outer whorls with more distant ribs without lateral tubercles but with prominent sporadic ventrolateral tubercles.

Material. — Thirteen specimens, well preserved on one side, crushed or covered with matrix on the other, mostly macroconchs: ten from loc. 22 (McM - J 1508/1-3, 6-8, 37, 76, 78, 92); two from loc. 32 (McM - J 1511/11, 55); and two from loc. 19A (McM - J 1515/11). J - 1508/7 and J 1511/55 are probably microconchs. J 1508/78 is at UNAM.

Description. — The shell is only moderately planulate and evolute. The whorl section is circular to depressed oval in the earlier whorls, becoming inflated subquadrate in the later whorls. The flanks are weakly convex to parallel; the umbilical wall is vertical with rounded shoulder.

The inner whorls carry rather dense sharp ribs, of which some are simple, others are branched. The ribs on the middle whorls arise at the umbilical seam and are rectiradiate to slightly prorsiradiate. Some ribs are simple, others are forked at approximately 3/5th whorl height. The posterior branch of some forked ribs tends to be rursiradiate. On the intermediate whorls, every third or fourth secondary carries a tubercle on the ventro-lateral shoulder; on the last whorl, the ventral tubercles are reduced to swellings. The mid-ventral area of the outer whorls is consistently crossed by reduced ribs. The probable microconch resembles the inner whorls of the macroconch. While septal sutures are not visible, adulthood of the small specimens is indicated on at least one of the two specimens by egression of the body chamber. The septal suture of the holotype (Text-fig. 29C) at a whorl height of 17 mm has a shallow E, a deeper L, and two or, possibly, three U lobes; the E/L saddle has a deep incision.

Remarks. — The ornamentation of *D. alencasteri* includes mainly the "typical stage" of Burckhardt (1912, p. 144-145).

D. rarifurcatus Imlay (1939, p. 48, pl. 17, fig. 8) is distinguished by the more evolute whorls and the more distinct and mostly simple ribs of the outer whorls. *D. vulgaris* Burckhardt (1912) [syn.?: *D. densestriatus* Burckhardt, 1912] is much more compressed and usually more densely ribbed. *D. humboldti* Burckhardt (1912) and its synonyms appear to be more involute than our species.

Occurrence. — El Verde Member, La Caja Formation, Sierra Catorce.

Age. — Upper Tithonian.

Measurements (figured specimens only). —

	D	U	U/D	H	W	H/W	P/wh.
Holotype ♀	62.0	22.3	0.35	24.0	20.0	1.20	51
Allotype ? ♂	39.0	14.0	0.35	15.5	—	—	35
MCM - J 1508/1 ♀	41.0	13.0	0.31	18.0	11.0	1.6	c.35
Paratype	60.0	18.0	0.30	21.5	19.5	1.0	—

Durangites ? n. sp. indet.

Pl. 56, fig. 6

Material. — One specimen from loc. 32 (McM - J 1511/17), a well-preserved adult phragmocone, exposed on one side and venter.

Description. — The shell is discoidal, involute. The umbilicus is narrow and deep with almost vertical wall and sharp shoulder. The flank is weakly convex and the venter flat. The whorl section varies from subquadrate to subovate. The lower part of the flanks has coarse primary ribs (24 on outer whorl), which bifurcate or trifurcate in the earlier whorls but could be virgatotome or fasciculate in the later ones; the branching zone in the later part of the outer whorl is ill defined. The secondaries (32 in the outer quarter whorl) are weakly projected and cross the venter without weakening or change in direction. Some secondaries on the early part of the outermost whorl carry small tubercles at the ventro-lateral margin; at least nine tubercles are present.

Remarks. — This specimen is tentatively placed in *Durangites* mainly because of the distinct sporadic ventro-lateral tubercles on the early part of the outer whorl. Enay (*in litt.*) collected similar specimens from southern Spain which in his opinion could be macroconch *Durangites*. However, the coiling is rather involute, and virgatotome and fasciculate ribbing are unknown from *Durangites*. This specimen cannot be placed in *Virgatosphinctes* Uhlig because of the tabulate venter. The rather coarse primaries and the involute coiling are reminiscent of *Nothostephanus* Spath, which has also a rounded venter. *Pseudoinvoluticeras* Spath is ruled out because of the tabulation and the absence of fine ribbing.

Occurrence. — El Verde Member, La Caja Formation, Sierra Catorce.

Age. — Upper Tithonian.

Measurements. —

	D	U	U/D	H	W	H/W	P/wh.
McM - J 1511/7	63.0	13.0	0.20	32.0	20.0	1.6	24

SUMMARY

1. The stratigraphy of the Upper Jurassic rocks of Sierra Catorce is now better known. The only richly fossiliferous stratigraphic unit is identified with the (mainly Tithonian) La Caja Formation of northern Mexico. It is underlain by the Oxfordian Zuloaga Limestone and overlain by the Cretaceous (Valanginian) Taraises Formation. An erosional unconformity separates the La Caja and the Zuloaga. Beneath the Zuloaga occurs the Huizachal Formation known from northern and eastern Mexico. Details of the stratigraphy and structure of four sections and several smaller outcrops of the La Caja (maximum exposed thickness 53 m) are reported. On the basis of the ammonite fauna and lithology, the La Caja formation is here divided into two parts, *i.e.* the El Pastor Member, below, and the El Verde Member, above. About 3 m above the base of the La Caja occurs a thin horizon with *Idoceras* spp. indicating the Kimmeridgian stage. The upper part of the El Pastor Member contains a small interval (up to 3 m) of richly fossiliferous beds here named the Virgatosphinctinae beds (late Lower Tithonian). The El Verde Member has abundant but sporadically distributed Upper Tithonian ammonites. The sections are correlated on the basis of the fauna and lithology. Detailed sampling from 40 different localities in the Sierra yielded an extremely rich fauna, of which only the ammonites are studied.

2. The taxonomic revision of the Tithonian ammonite assemblages of Sierra Catorce is based upon much larger, systematically collected and better preserved samples than those of the previous authors. Of the 25 alleged new Upper Jurassic ammonite (including 1 "*Nautilus*") species originally described by Aguilera (*in* Castillo and Aguilera, 1895), only the following thirteen can be identified with certainty: *Kossmatia alamosensis*, *K. exceptionalis*, *K. bifurcata*, *K. flexicostata*, *Physodoceras* (subgen. nov. ?) *burkartii*, *Aspidoceras alamosense*, *Aulacosphinctoides potosinus*, *A. lauri*, *Andi-*

ceras lenki, *A. monserati*, *Mazapilites mexicanus*, *Durangites heilprini*, and *D. cohglani*. All but *Aspidoceras alamtocense* were transferred to different genera.

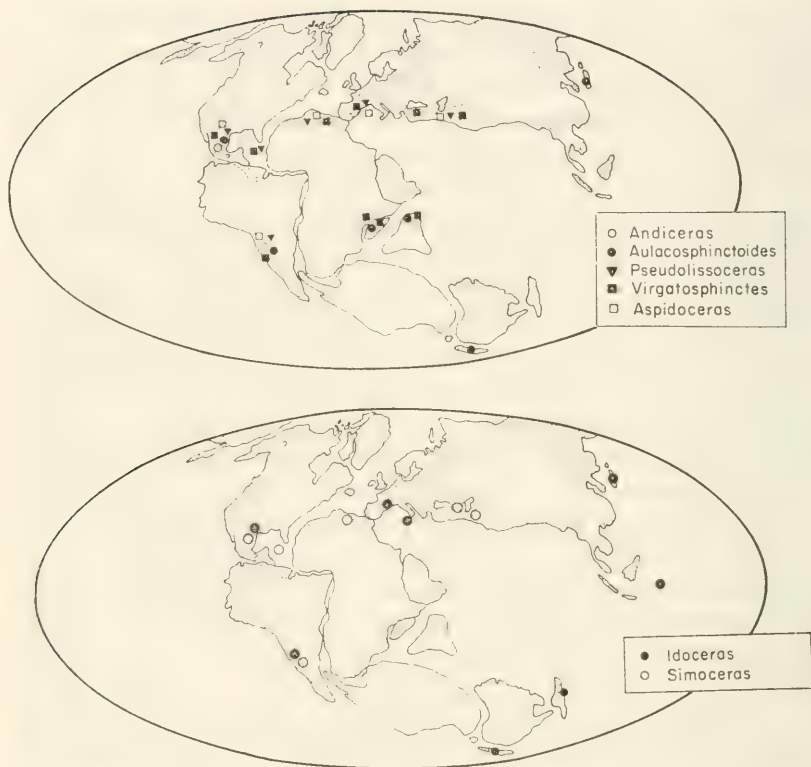
The remaining alleged new species include (i) 5 which are doubtful or synonymous with the above-mentioned species, and (ii) 7 which are regarded as *nomina dubia*. The latter group includes alleged species based upon extremely poor material which has been lost or of which no additional material is available.

3. From the present collection a total of 52 species are described belonging to 20 genera and 6 families of Ammonoidea. Of these 31 are identified and 10 compared with previously known species while 5 and possibly a total of 9 are new. Newly named are: *Virgatosphinctes sanchezi*, *Kossmatia purissima*, *Substeueroceras catorcense*, *Corongoceras cordobai* and *Durangites alencasteri*. One new subspecies is named: *Substeueroceras koeneni* (Steuer) *tabulatum*.

4. Of a total of 20 genera, 11 are reported from Sierra Catorce for the first time: *Pseudolissoceras* Spath, "*Paraglochiceras*" Collignon, *Pseudoinvoluticeras* Spath, *Virgatosphinctes* Uhlig, *Simoceras* Zittel, *Physodoceras* Hyatt, *Substeueroceras* Spath, *Andiceras* Krantz, *Corongoceras* Spath, *Micracanthoceras* Spath, *Durangites* Burckhardt.

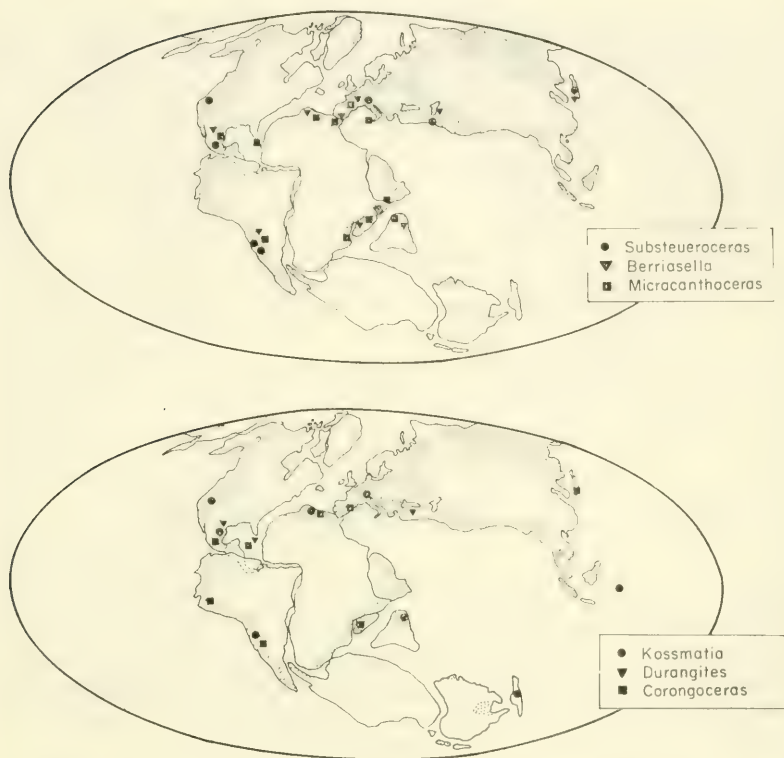
5. The following 12 species and one subspecies appear to be present in sexual dimorphs; significantly, this includes almost all more abundant taxa: *Pseudolissoceras zitteli* (Burckhardt), *Aulacosphinctoides lauri* (Aguilera), *Subdichotomoceras*, n. sp. aff. *S. inversum* Spath, *Virgatosphinctes sanchezi*, n. sp., *Kossmatia alamtocensis* (Aguilera), *K. bifurcata* (Aguilera), *K. exceptionalis* (Aguilera), *K. flexicostata* (Aguilera), *Substeueroceras catorcense*, n. sp., *S. koeneni tabulatum*, n. subsp., *Andiceras monserati* (Aguilera), *Corongoceras cordobai*, n. sp. and *Durangites alencasteri*, n. sp.

6. Four distinct assemblages can be recognized. The lowest is the poorly developed Kimmeridgian *Idoceras* assemblage with only three species of *Idoceras*. The next higher one is the diverse assemblage of the *Virgatosphinctinae* beds which contains *Aulacosphinctoides*, *Andiceras*, *Virgatosphinctes*, and *Pseudolissoceras* as major elements, and *Phylloceras*, *Aspidoceras*, *Simoceras*, *Haploceras*, "*Para-*



Text-fig. 30. — Geographic distribution of Lower Tithonian and Kimmeridgian ammonite genera known from the Sierra Catorce. Areas of maximal marine transgression are dotted. (Distribution of continents modified after Wilson, 1963; Smith and Hallam, 1970).

glochiceras", *Pseudoinvoluticeras*, and *Mazapilites* as minor elements. There follow the rich *Kossmatia-Durangites-Corongoceras* assemblage and, finally, the *Substeuerocheras-Berriasella* assemblage. 7. A comparison with the assemblages from northern Mexico indicates general agreement with a few minor anomalies; the most important is the impoverishment in involute compressed forms like



Text-fig. 31. — Geographic distribution of Upper Tithonian ammonite genera (as indicated) known from the Sierra Catorce. Areas of maximal marine transgression are dotted. (Distribution of continents modified after Wilson, 1963; Smith and Hallam, 1970).

Mazapilites and *Haploceras* in the Sierra Catorce. A global comparison at the species level indicates that the Sierra Catorce fauna is most closely affiliated with the Tithonian fauna of Argentina while Mediterranean affinities are somewhat more distant. Boreal elements are unknown.

8. The assemblage of the *Virgatosphinctinae* beds combines elements of two Argentine zones of the late Lower Tithonian, *i.e.* the Zones of *Pseudoplissoceras zitteli* and of *Virgatosphinctes mendo-*



Text-fig. 32. — Paleogeographic map of Mexico for the Upper Jurassic; X, location of the Sierra Catorce; O, area of classical localities further north (modified after Imlay, 1940, 1965).

zanus; the *Kossmatia-Durangites-Corongoceras* assemblage is probably in part equivalent to the Argentine Zone of *Corongoceras alternans*; and the *Substeueroceras-Berriasella* assemblage can be placed in the Argentine Zone of *Substeueroceras koeneni* which is therefore extended geographically.

9. The relative abundance of benthic fauna (brachiopods, bivalves), clastics and of strongly ornate forms among the ammonites suggests that the La Caja Formation of Sierra Catorce was deposited in shallower waters than hitherto believed.

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PLATES

EXPLANATION OF PLATE 22

Figure

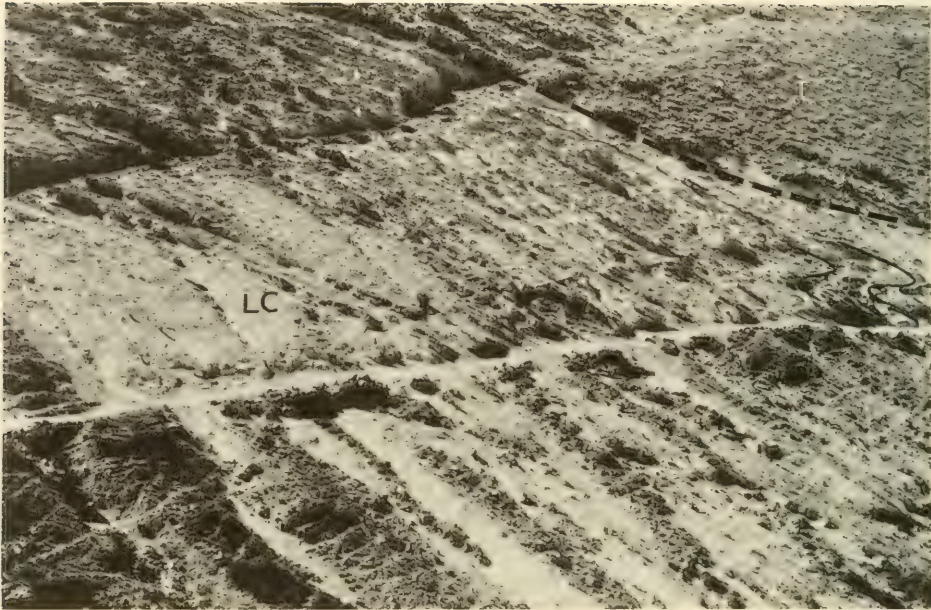
1. Distant view of Real de Catorce (alt. 2757 m) looking west. The surrounding hills comprise mainly the Huizachal Formation (Lower = LH, Upper = UH) and Zuloaga Limestone (Z). The La Caja Formation outcrops occur mainly east and south of Real de Catorce.
2. Large outcrop of La Caja Formation, mainly the El Pastor Member, and Zuloaga Limestone, south of Los Alamitos; LC = La Caja Formation; Z = Zuloaga Limestone; O = Virgatosphinctinae beds. The rocks are folded into a tight syncline; X marks the core. The west limb of the syncline is highly sheared; wavy lines indicate shear zone.



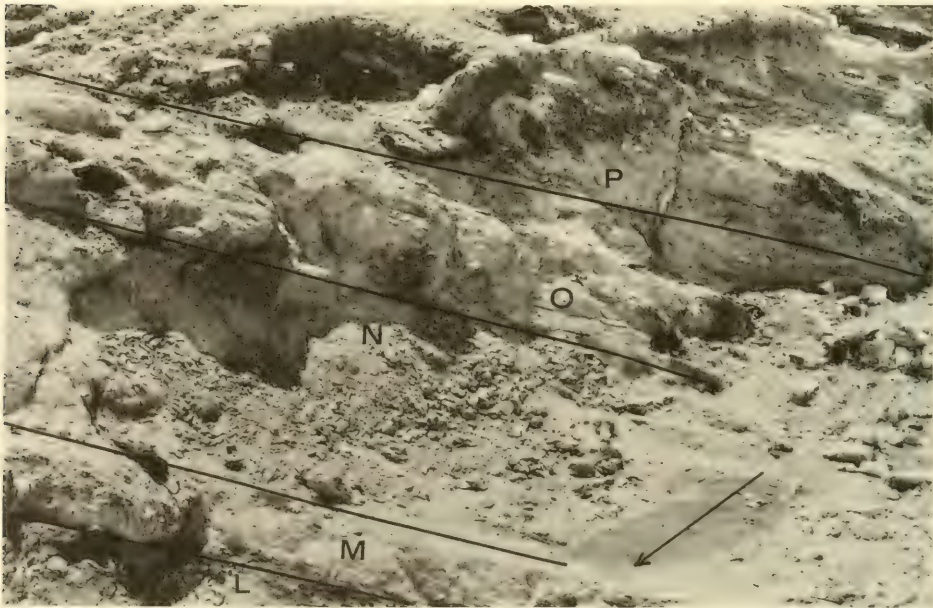
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EXPLANATION OF PLATE 23

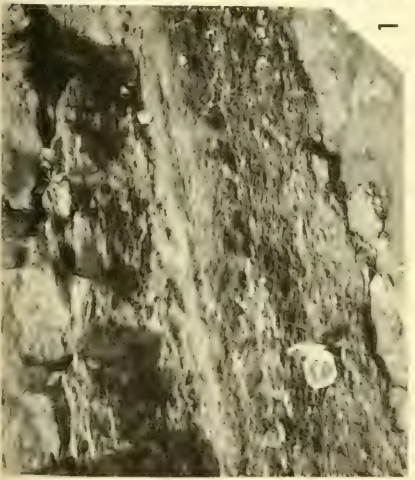
Figure

1. Stratotype of El Verde Member, upper La Caja Formation; east limb of anticline immediately north of El Verde; LC = La Caja Formation, T = Taraises Formation. Wavy lines near the top of the La Caja at the lower mule track indicate minor structural disturbance.
2. Close up of beds 'l'-p' of the El Pastor Member, La Caja Formation, exposed in a stream cut of El Pastor; stratotype of El Pastor Member; O = Virgatosphinctinae beds. Arrow indicates the downstream direction (see Pl. 24, fig. 4).

EXPLANATION OF PLATE 24

Figure

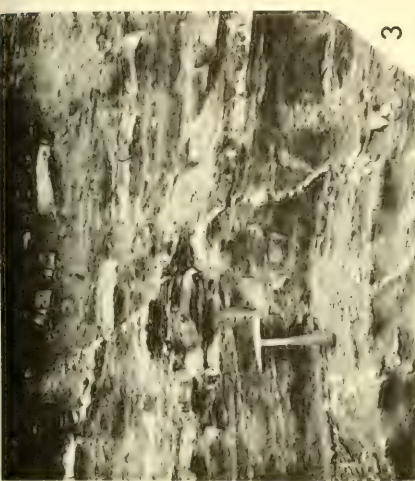
1. The basal part of El Pastor Member, La Caja Formation, in the stream cut at El Pastor. The lower bed contains pebbles derived from the underlying Zuloaga Limestone. The bed above contains *Idoceras*.
2. Thick beds of fine-grained, hard, grey limestone of the Zuloaga Limestone exposed along the jeep road from Real de Catorce to the El Compromiso mine.
3. Uppermost part of the El Verde Member, La Caja Formation, exposed at San Andres. Thin interbedded limestones and shales are affected by a small oblique fault.
4. Panoramic view of the stratotype of the El Pastor Member, La Caja Formation, exposed on the west bank of the stream at El Pastor. Most of the undisturbed part of the section is shown. O = *Virgatosphinctinae* beds (see Pl. 23, fig. 2).



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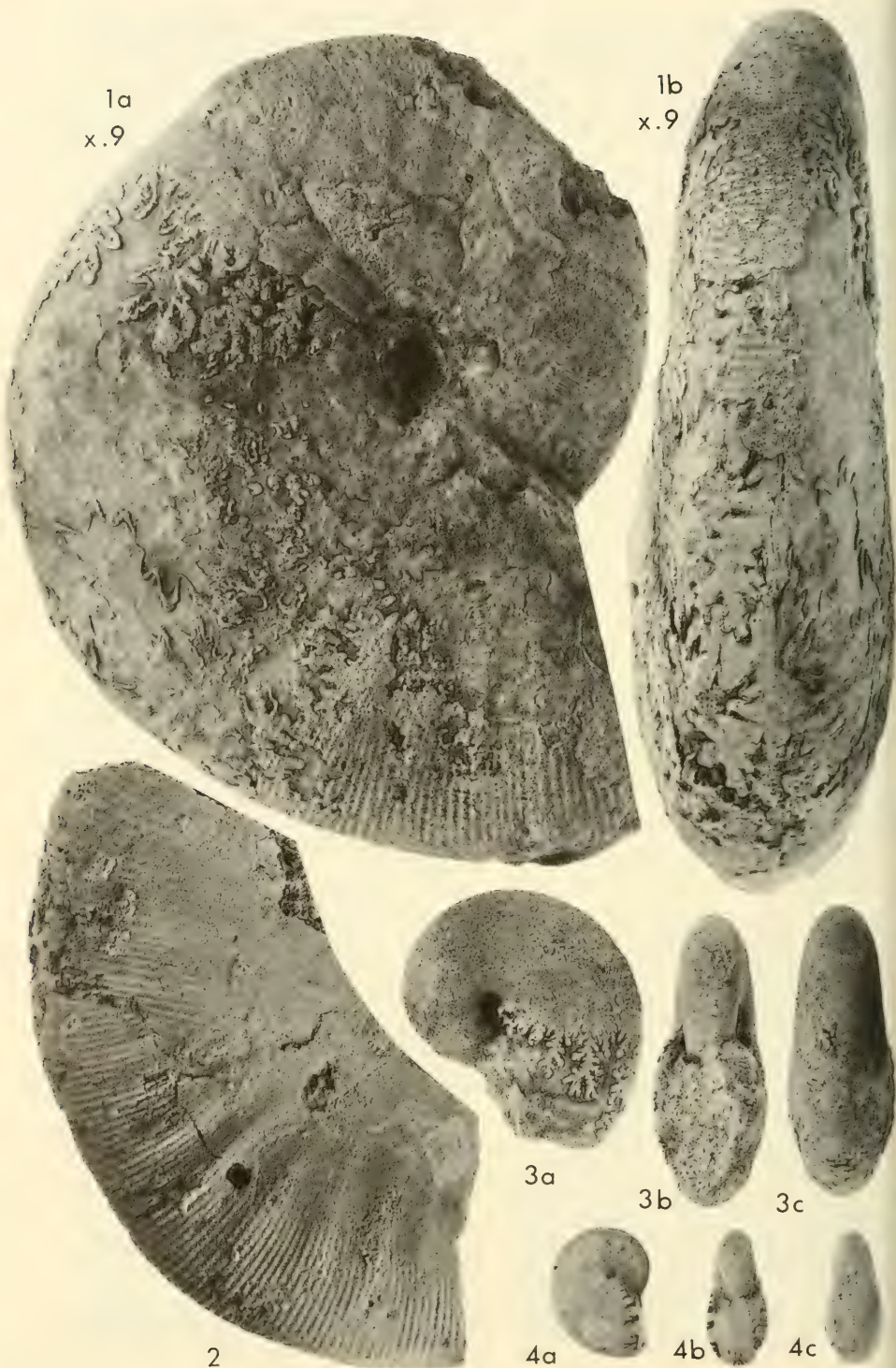
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EXPLANATION OF PLATE 25

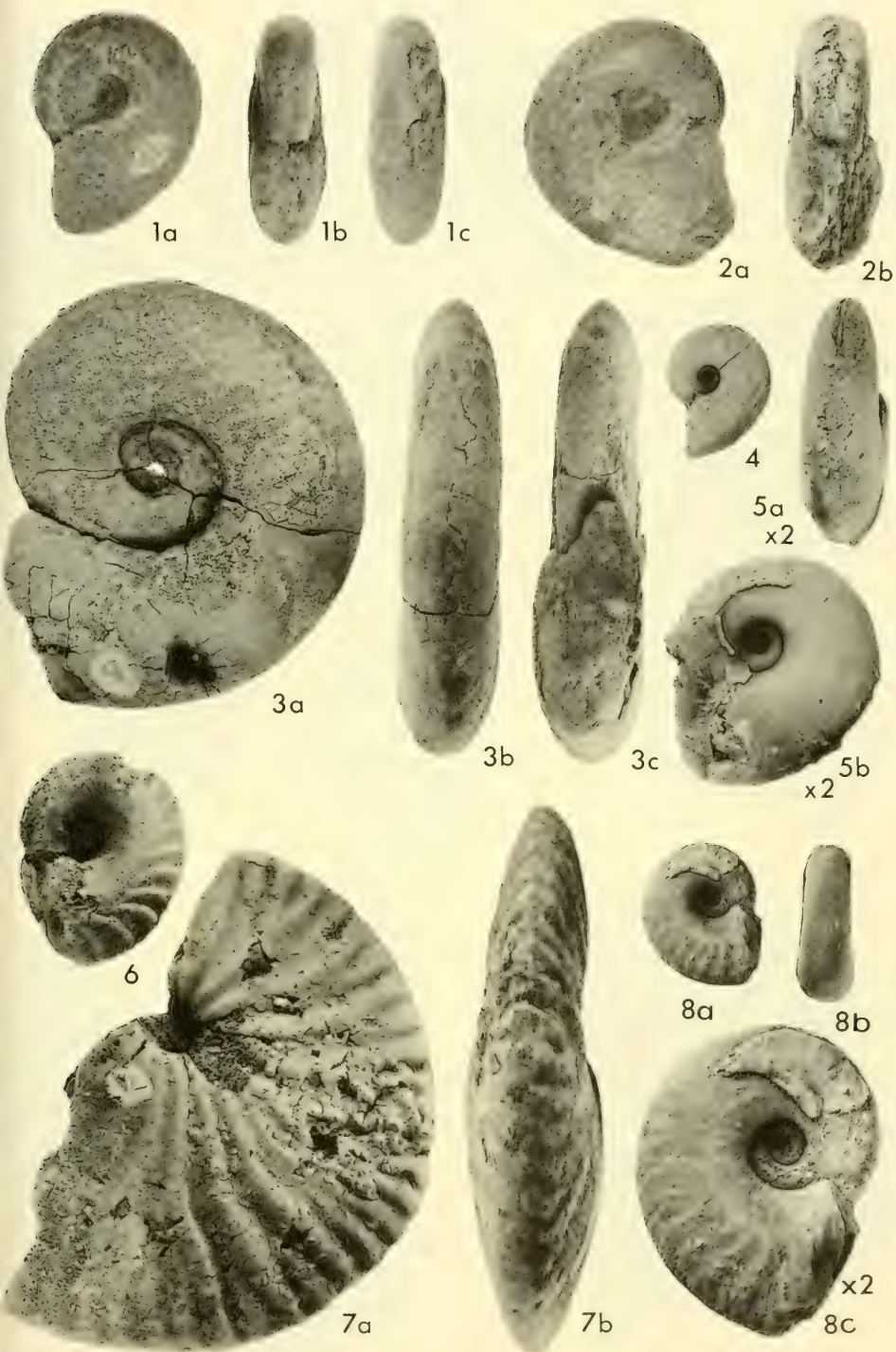
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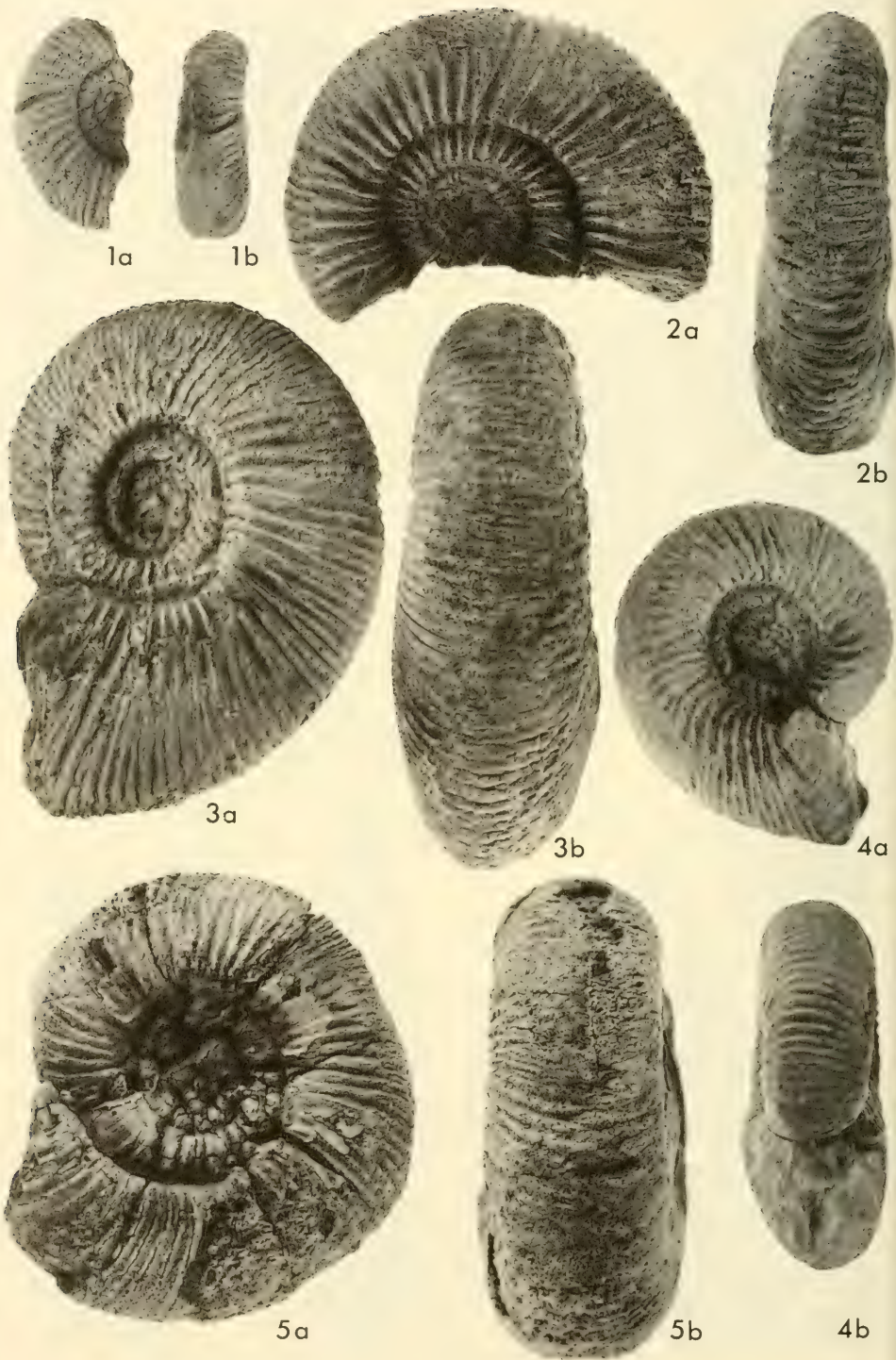
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All figures natural size unless indicated otherwise.

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EXPLANATION OF PLATE 27

All figures natural size unless indicated otherwise.

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EXPLANATION OF PLATE 28

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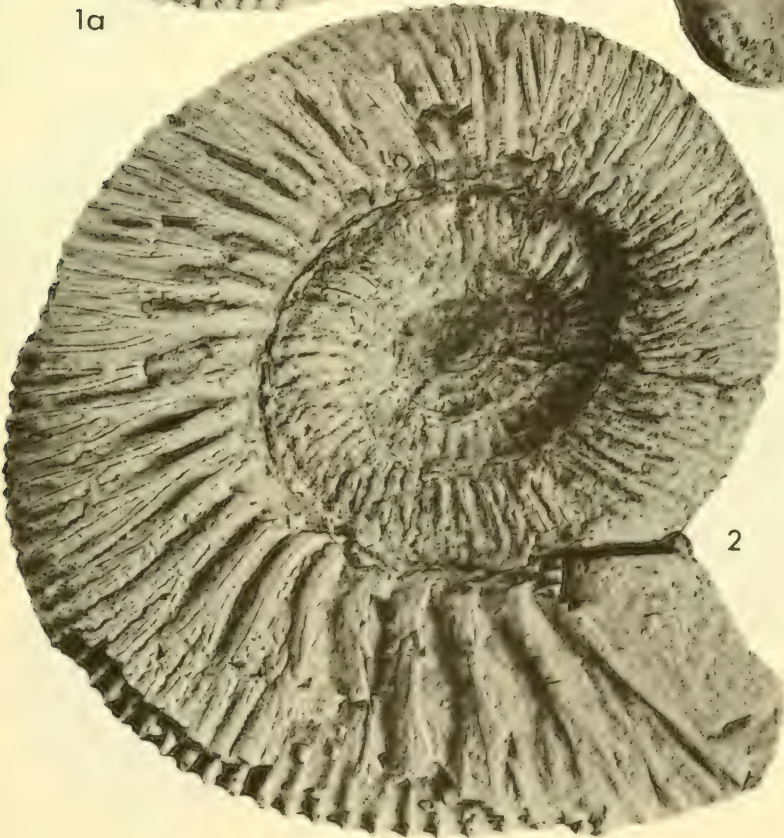
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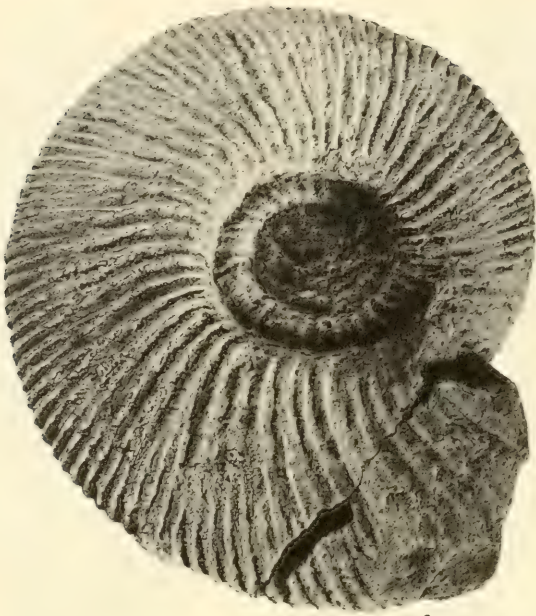
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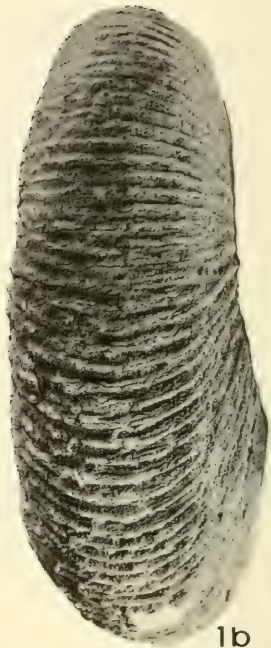
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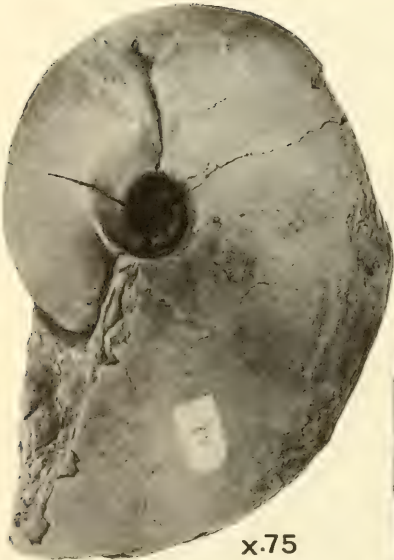
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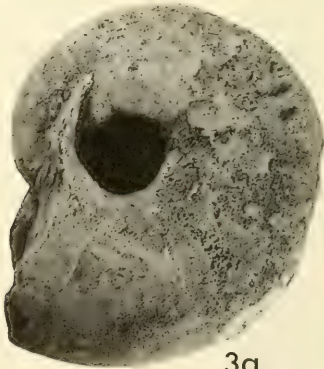
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3a



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EXPLANATION OF PLATE 29

All figures natural size unless indicated otherwise.

Figure	Page
1. Pseudoinvoluticeras cf. P. mozambicum Collignon	182
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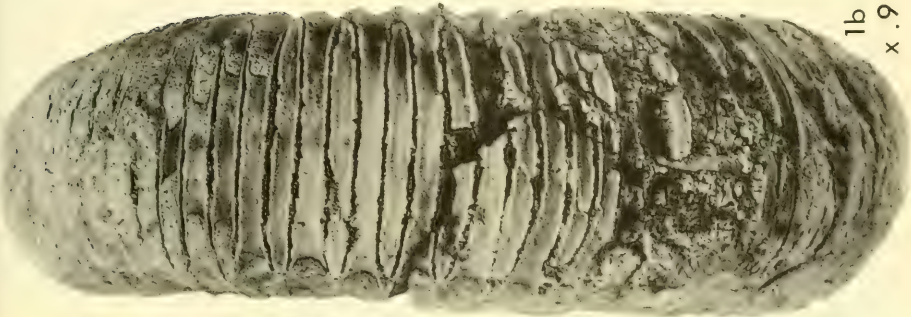
EXPLANATION OF PLATE 30

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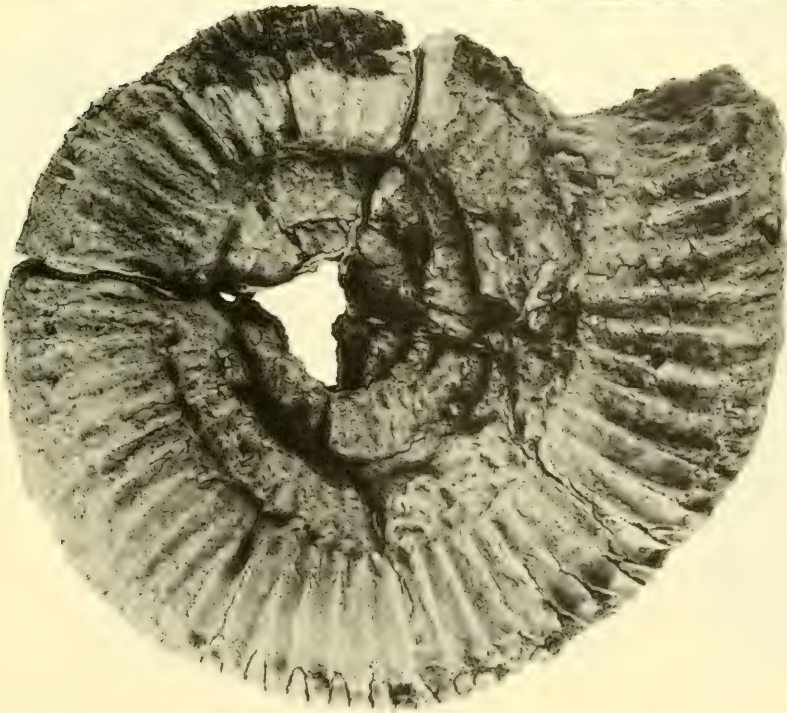
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1-2. Subdichotomoceras , n. sp. aff. A. inversum Spath	183
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x .8 1a



EXPLANATION OF PLATE 31

All figures natural size.

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1-2. Subdichotomoceras , n. sp. aff. S. inversum Spath	183
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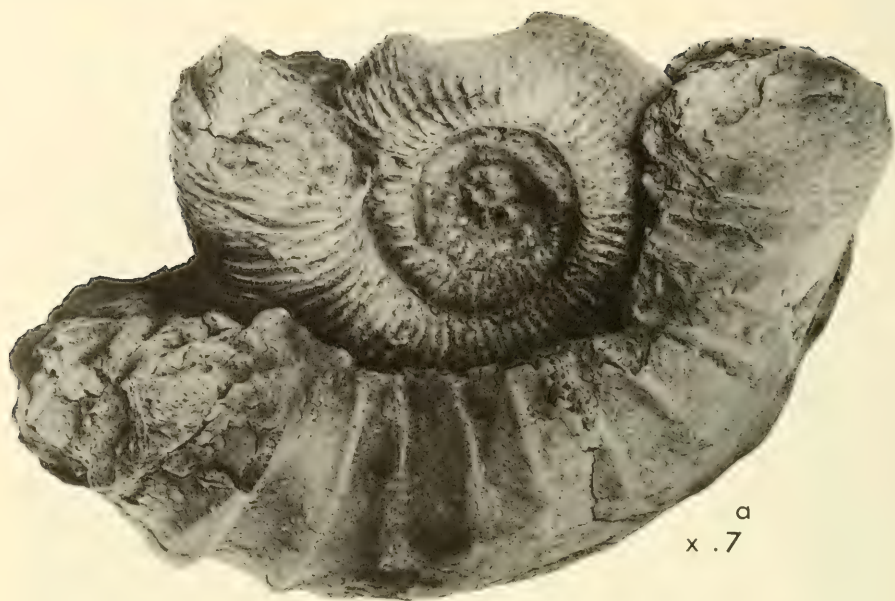
EXPLANATION OF PLATE 32

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	Page
Virgatosphinctes sanchezi Verma and Westermann, n. sp.	185
Virgatosphinctinae beds, El Pastor Member, La Caja Formation; upper Lower Tithonian. Holotype, macroconch (♀), giant specimen, complete, somewhat distorted, lateral view (McM - J 1528/2). Loc. 40C, El Pastor. $\times 0.3$.	



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EXPLANATION OF PLATE 33

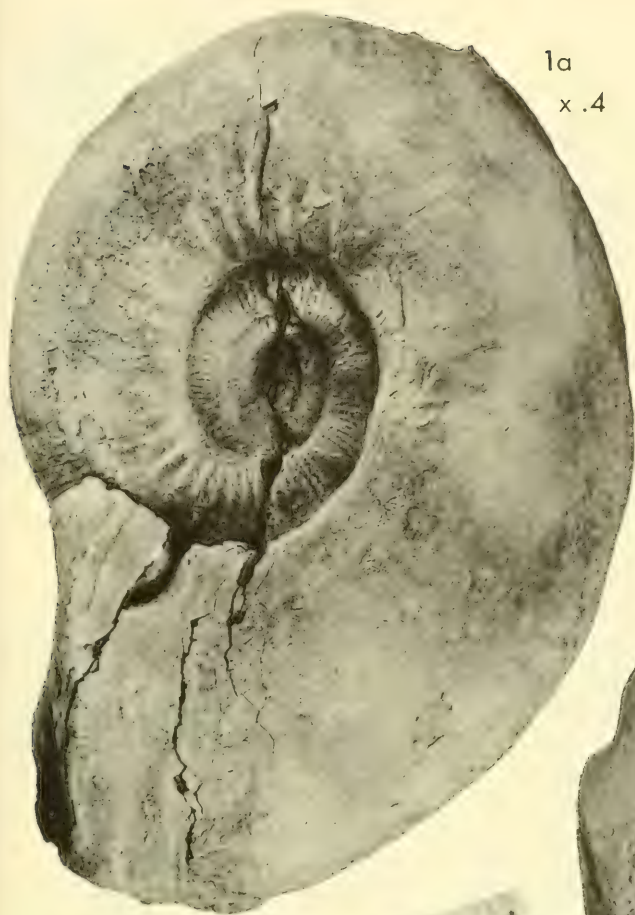
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	Page
Virgatosphinctes sanchezi Verma and Westermann, n. sp.	185
Virgatosphinctinae beds, El Pastor Member, La Caja Formation; upper Lower Tithonian. Paratype/allotype, ? microconch (δ) incomplete phragmocone and ? body chamber. — a. Lateral view; $\times 0.7$. — b-c. Lateral and ventral views of inner whorls (McM - J 1529/98). Loc. 40E, El Pastor.	

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All figures natural size unless indicated otherwise.

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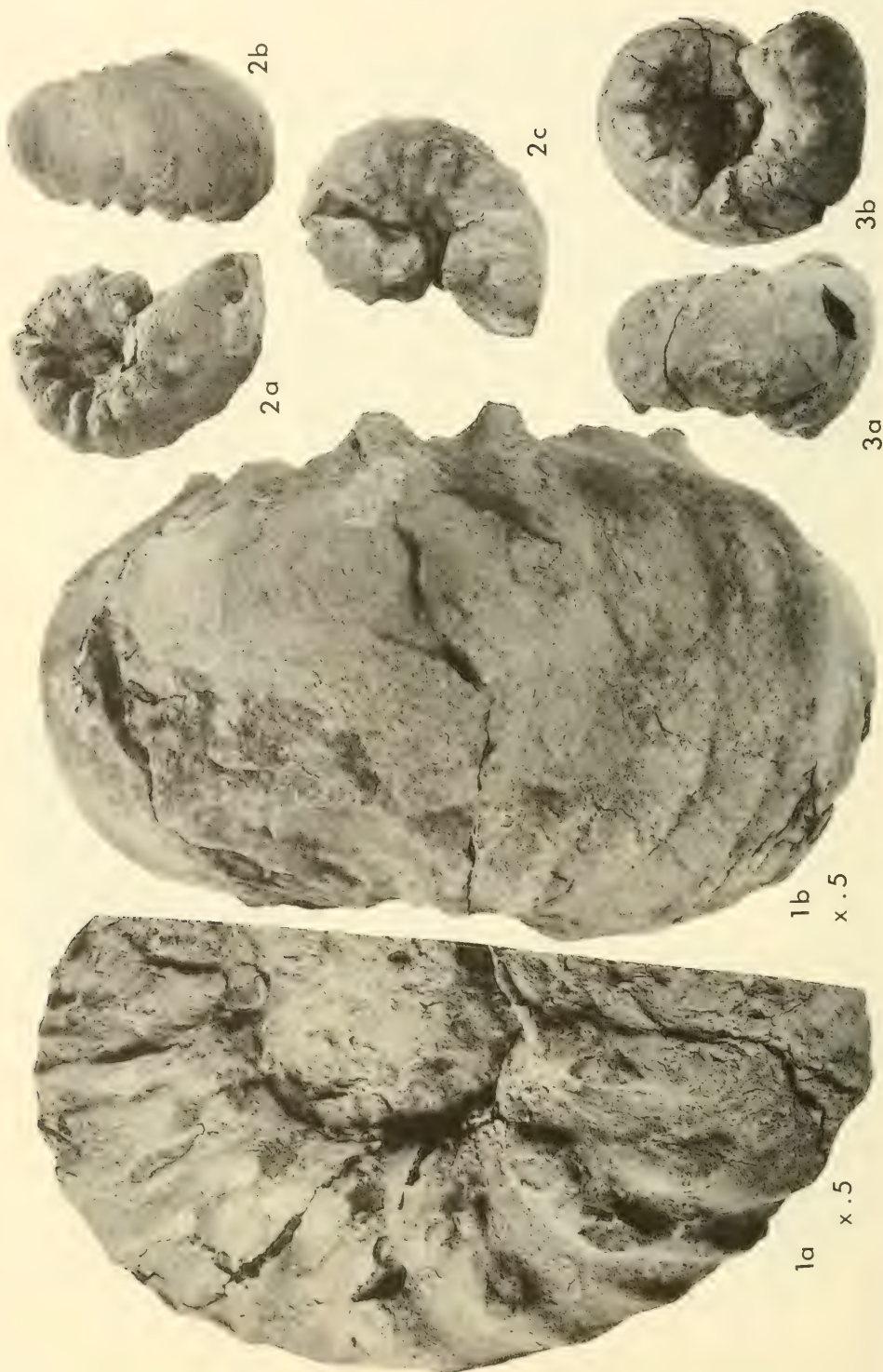
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EXPLANATION OF PLATE 35

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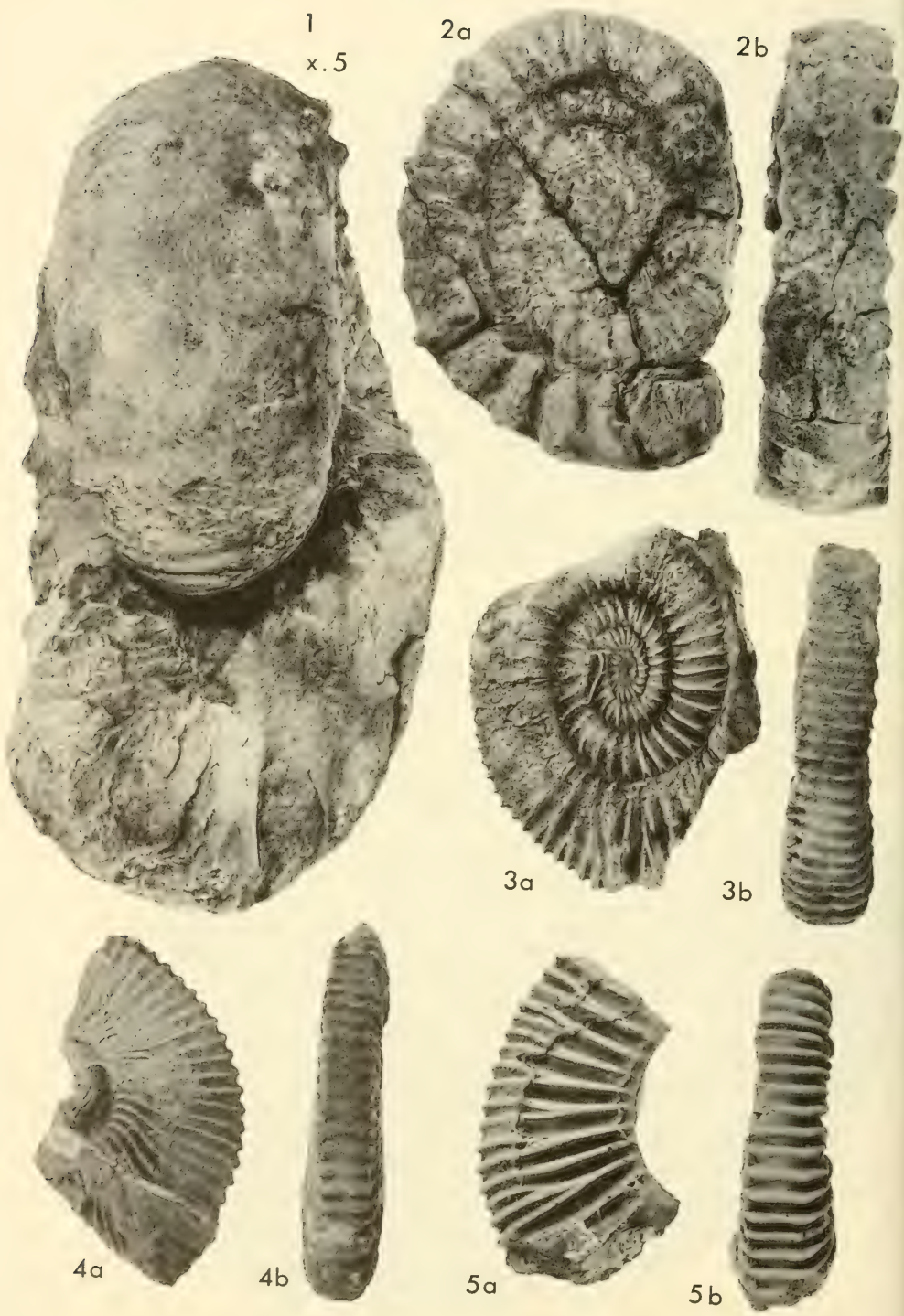
Figure	Page
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All figures natural size unless indicated otherwise.

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EXPLANATION OF PLATE 37

All figures natural size unless indicated otherwise.

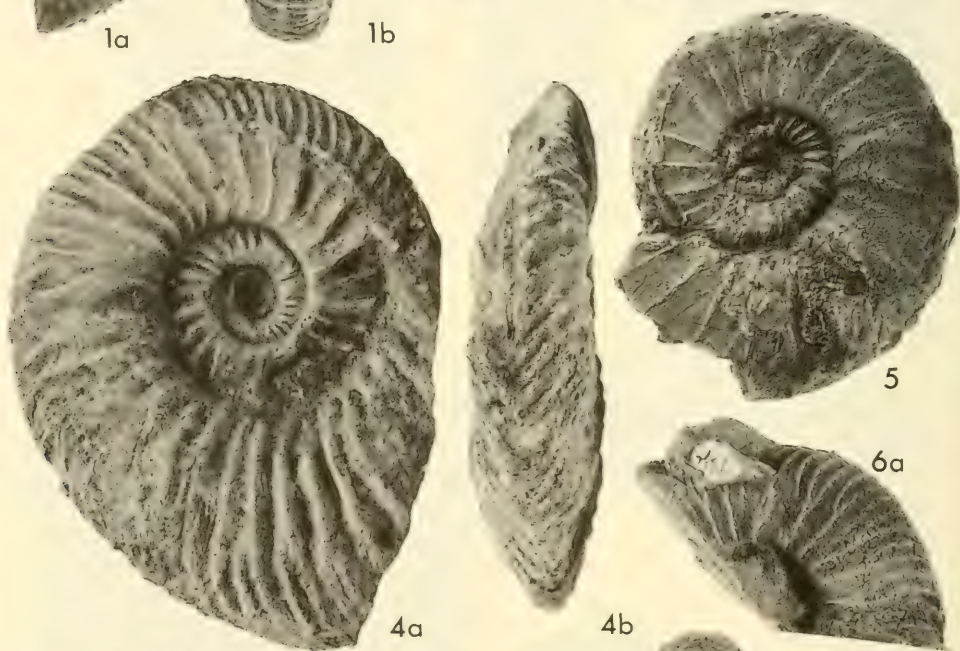
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All figures natural size.

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EXPLANATION OF PLATE 39

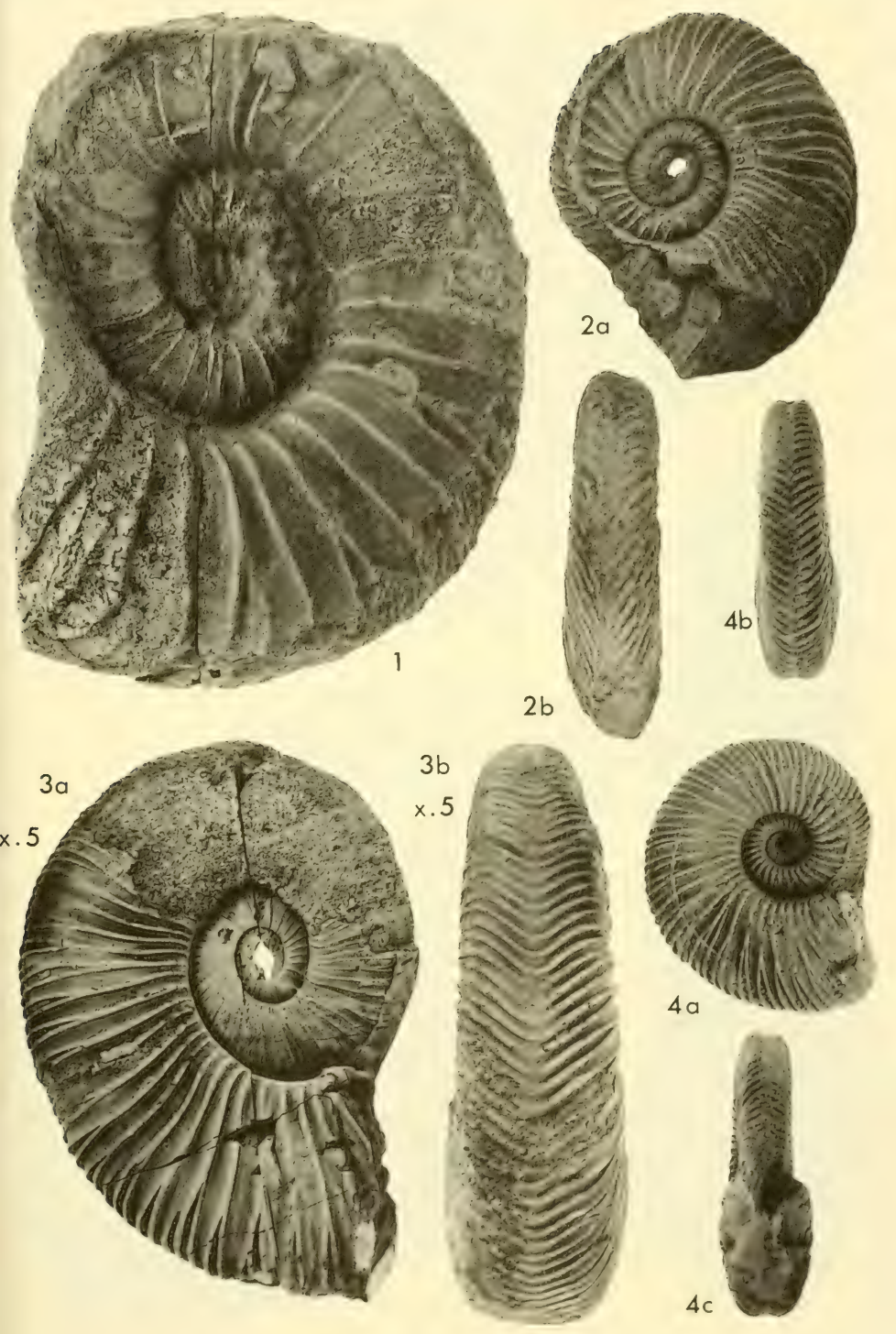
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All figures natural size unless indicated otherwise.

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EXPLANATION OF PLATE 41

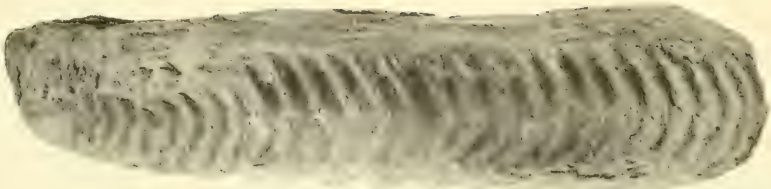
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Figure	Page
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El Verde Member, La Caja Formation; Upper Tithonian. — 1. Macroconch (♀), phragmocone (ill-preserved body chamber not shown), lateral view (McM - J 1526/90). Loc. 14A, El Verde; $\times$ 0.75. — 2a-b. Macroconch (♀), phragmocone, lateral and ventral views (McM - J 1526/31). Loc. 14A, El Verde; $\times$ 0.6.	

EXPLANATION OF PLATE 42

All figures natural size unless indicated otherwise.

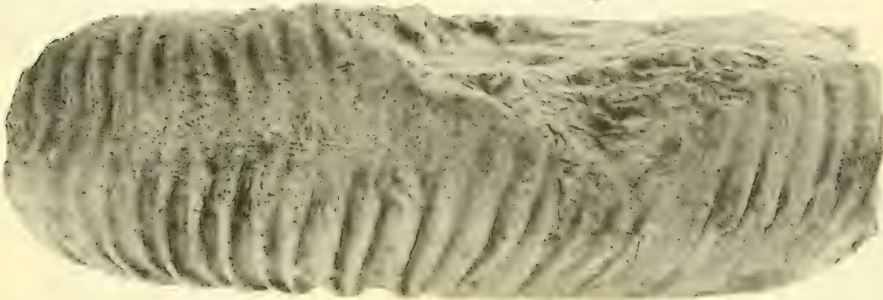
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El Verde Member, La Caja Formation; Upper Tithonian. —	
1a-b. Holotype (Aguilera <i>in</i> Castillo and Aguilera, 1895, pl. XX, fig. 1), macroconch (♀) whorl fragment, lateral and ventral views (UNAM 6). Loc. "Rancho Alamitos". — 2a-b. Body Chamber, lateral and ventral views (McM - J 1517/6). Loc. 25, La Leona; $\times$ 0.5.	



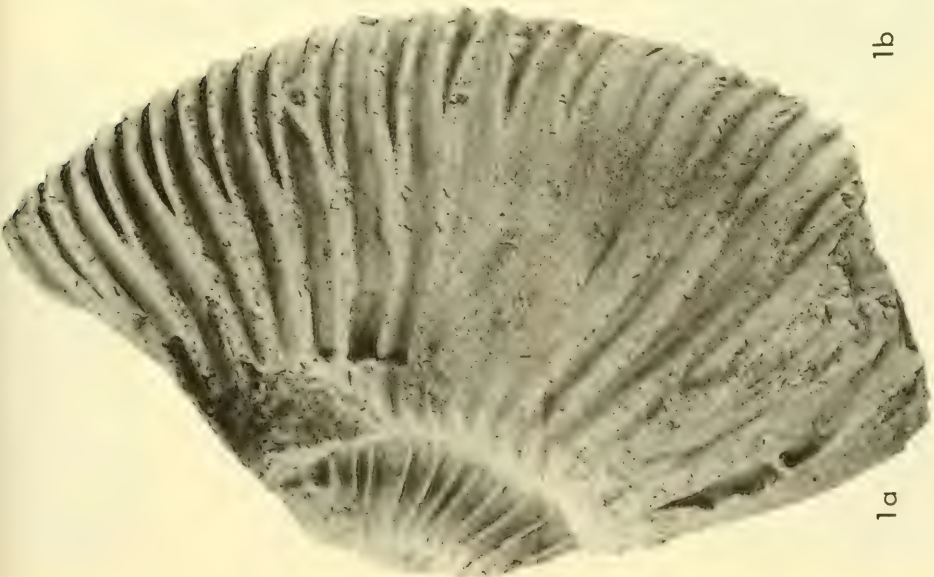
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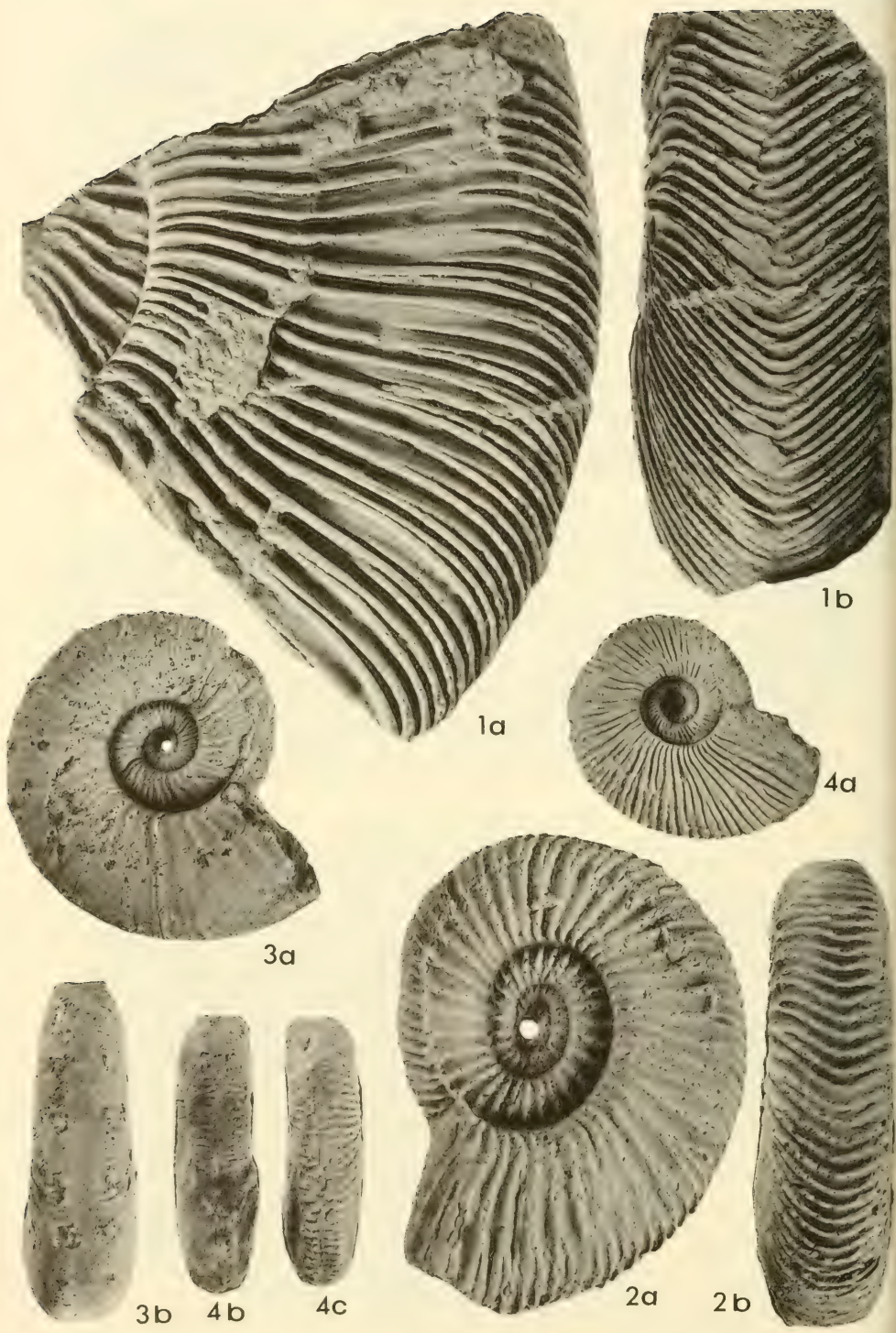
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1a



EXPLANATION OF PLATE 43

All figures natural size.

Figure	Page
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El Verde Member, La Caja Formation; Upper Tithonian. Holotype, macroconch (♀) phragmocone fragment, lateral and ventral views (UNAM 7). Loc. "Rancho Alamitos".	
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All figures natural size unless indicated otherwise.

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El Verde Member, La Caja Formation; Upper Tithonian. Holotype of " <i>Rhacophyllites ? disputabile</i> " Aguilera, macroconch (♀), incomplete adult phragmocone, lateral and ventral views (UNAM 30). Loc. "Rancho Alamitos"; $\times 0.7$.	





1a



1b

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x .6



EXPLANATION OF PLATE 45

All figures natural size unless indicated otherwise.

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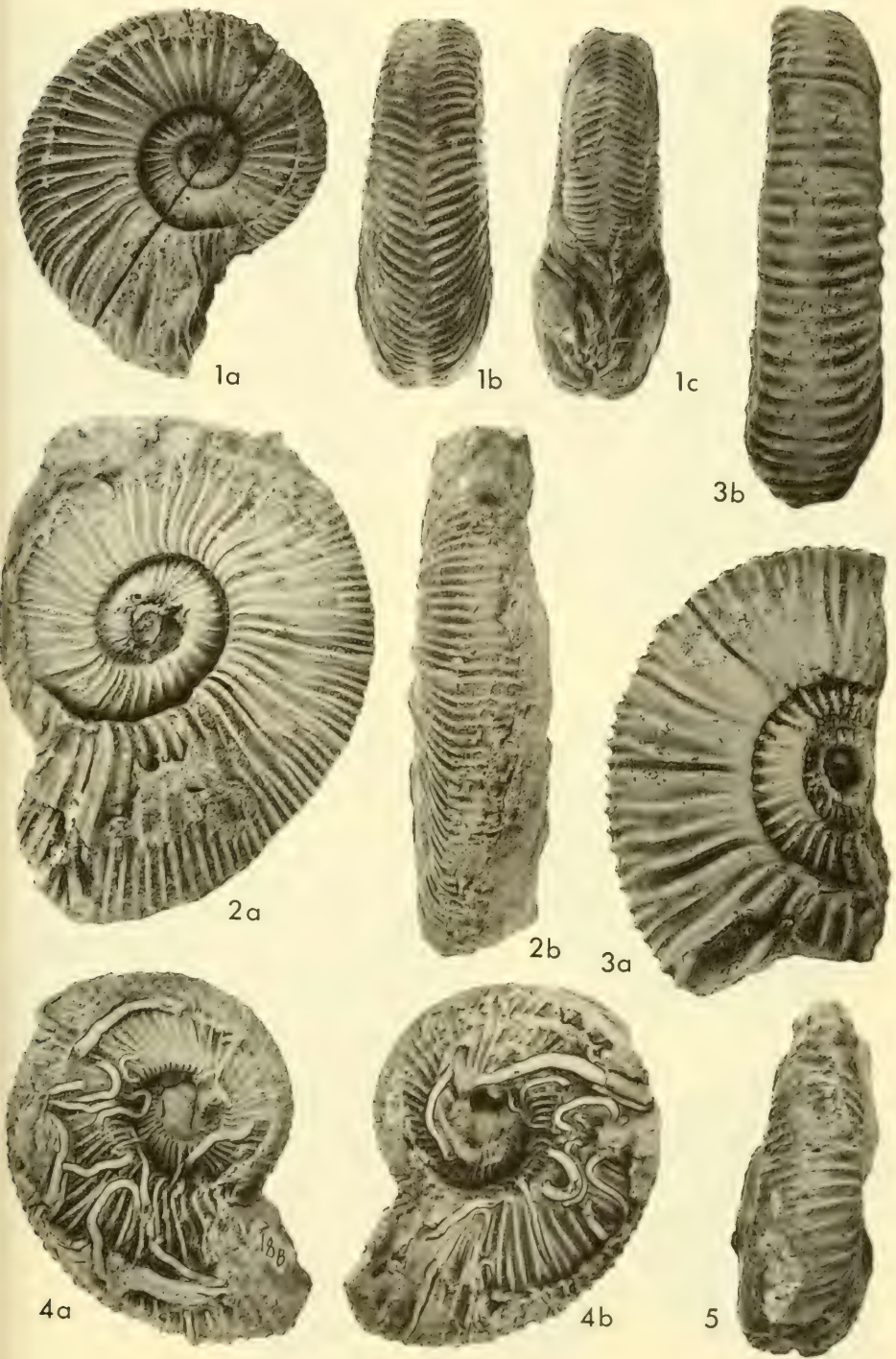
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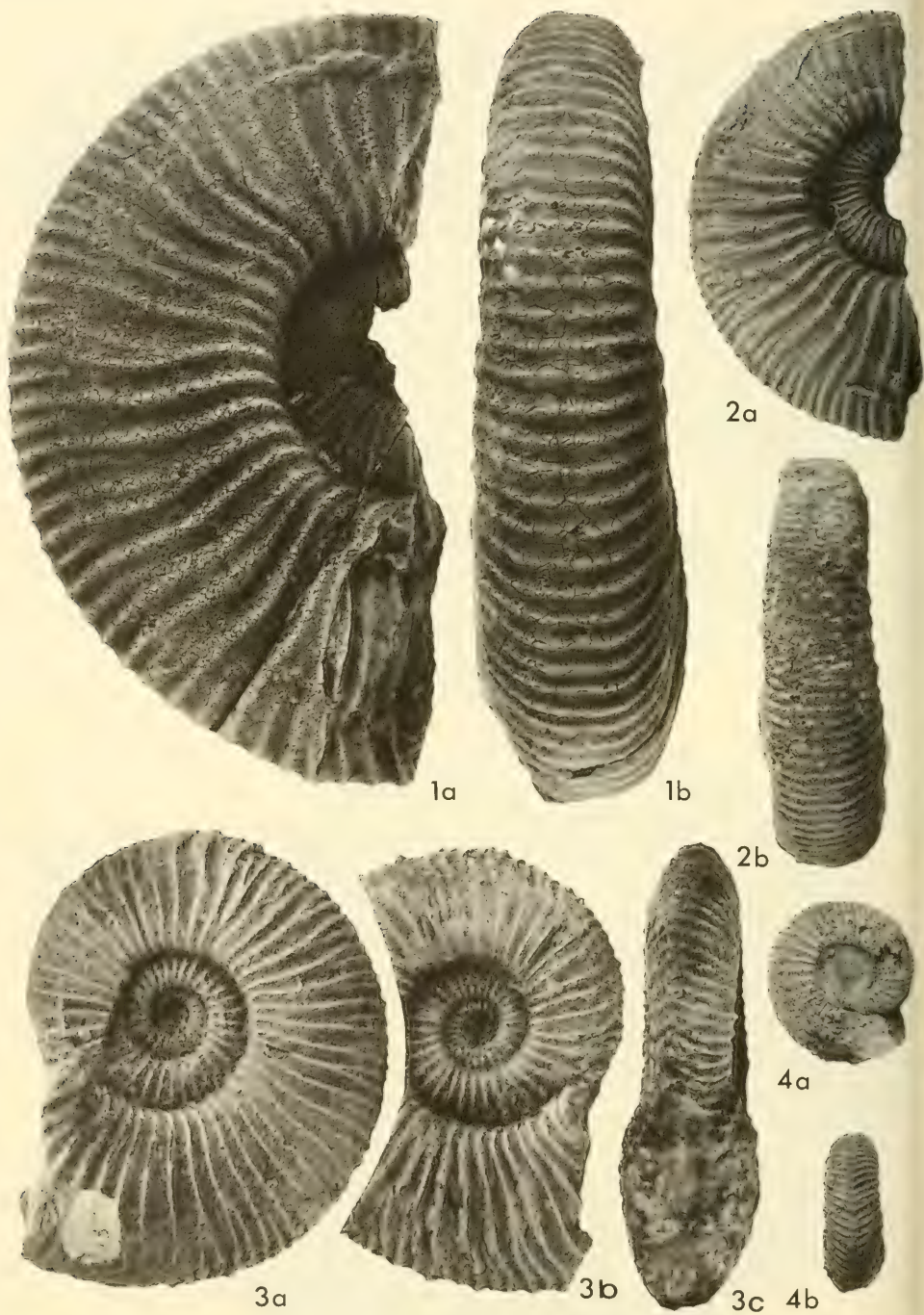
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1



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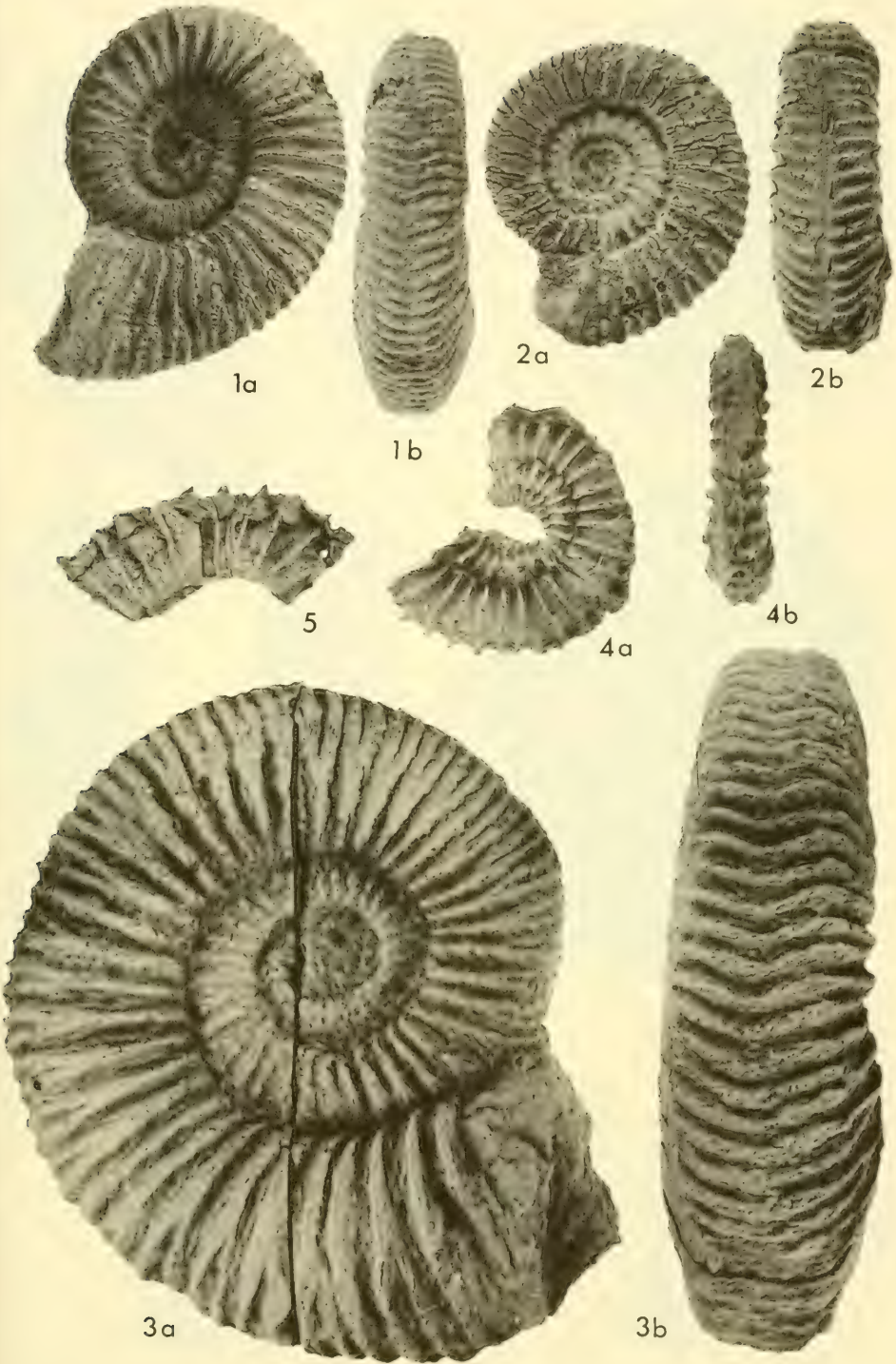
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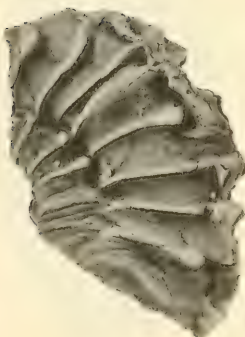
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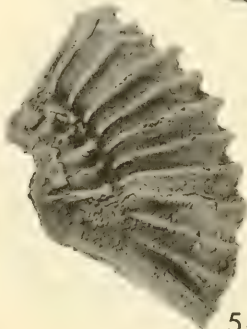
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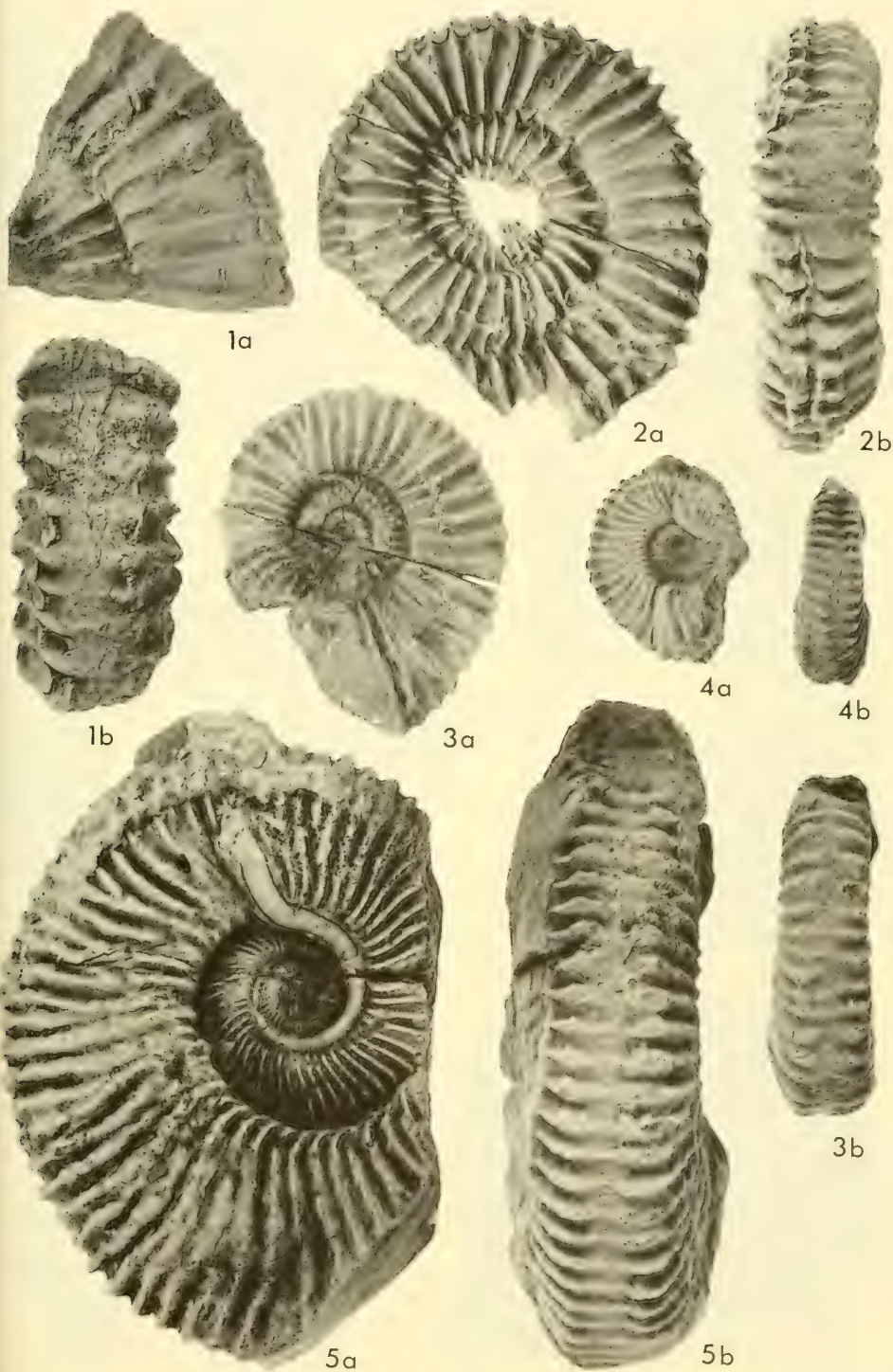
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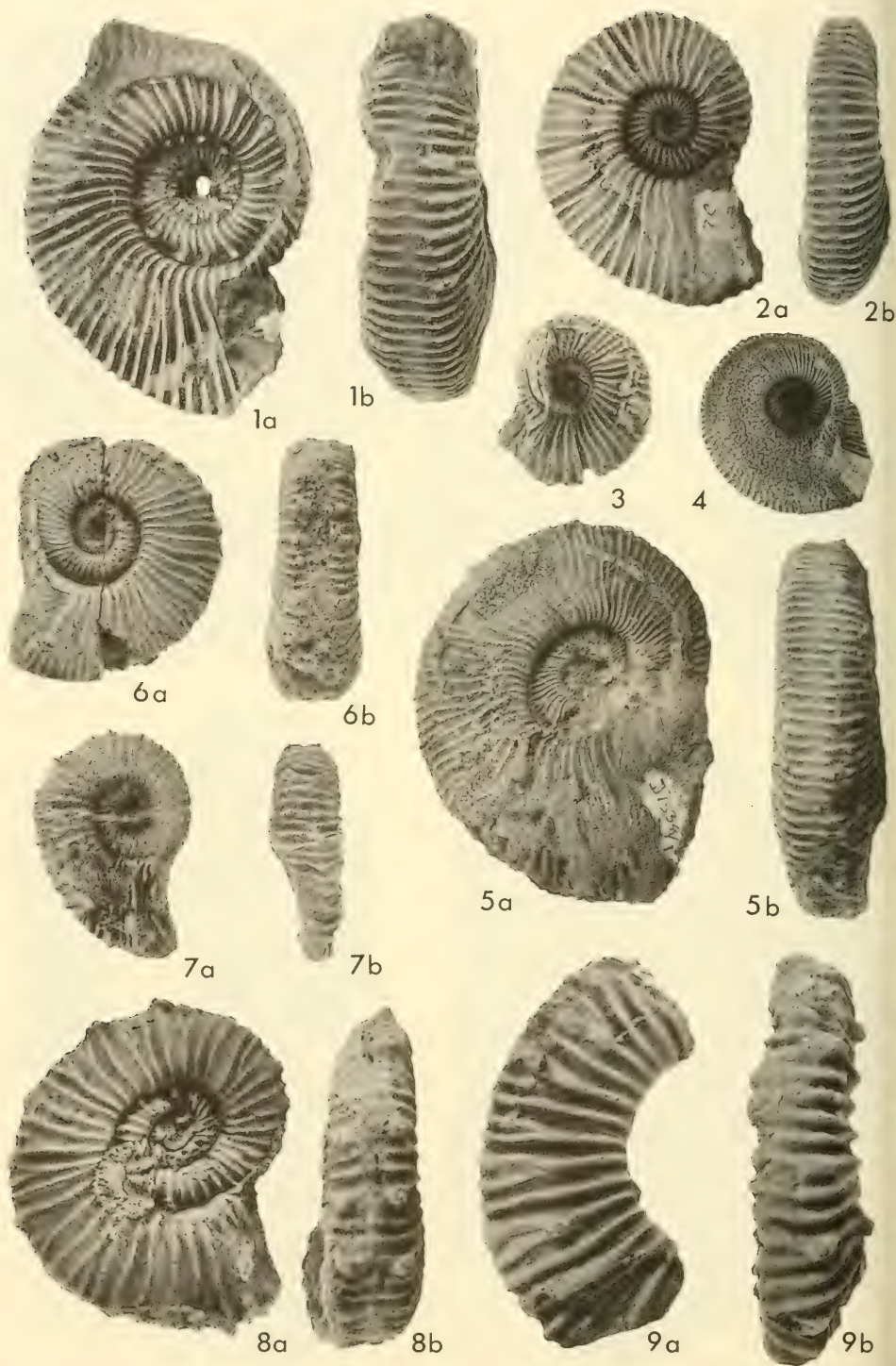
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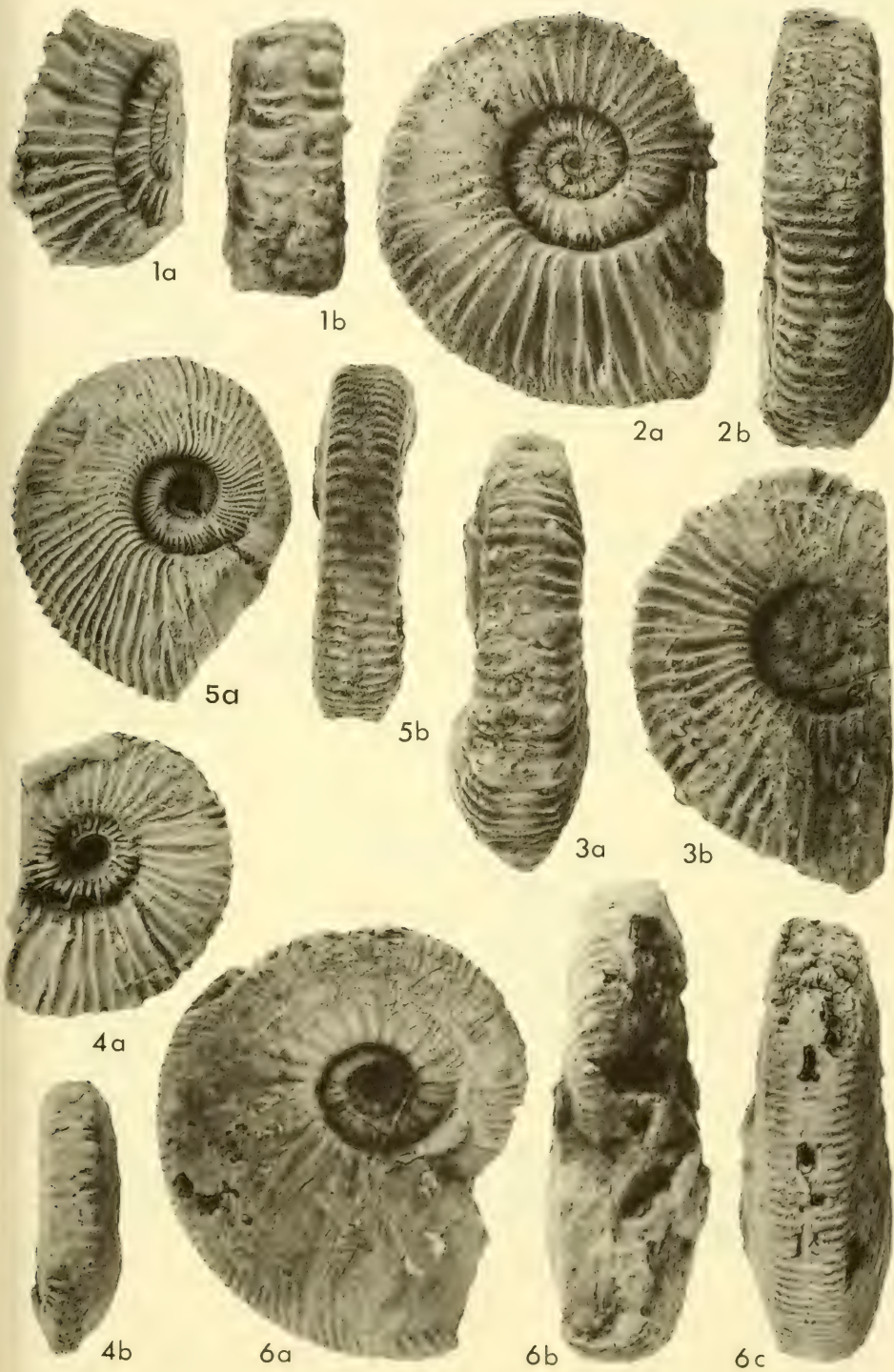
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